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THE MODERN PLUMBER AND SANITARY ENGINEER

TREATING OF PLUMBING, SANITARY WORK, VENTILATION, HEATING (ELECTRIC AND OTHER), HOT-WATER SERVICES, GAS-FITTING, ELECTRIC LIGHTING, BELL-WORK, GLAZING, &c.

BY SIXTEEN SPECIALIST CONTRIBUTORS

UNDER THE EDITORSHIP OF

G. LISTER SUTCLIFFE

A.R.I.B.A., M.R.S.I.

Editor of "The Principles and Practice of Modern House Construction", &c.

WITH APPENDICES OF
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Section VI.—HOT-WATER SERVICES

BY

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Section VI.—HOT-WATER SERVICES

CHAPTER I

WATER AND STEAM

Before attempting to design any system for the supply of hot water, it is essential that the natural laws which govern the success of such work should be thoroughly understood.

For the sake of clearness, the properties of water which are responsible in a greater or less degree for the efficiency of the work we are now discussing, may be divided into two classes: *Physical* and *Chemical.*

Physical Properties of Water.—Water, the chemical symbol of which is H_2O (denoting that its molecule consists of two atoms of hydrogen gas to one of oxygen), may exist in three states: (1) Solid, (2) Liquid, and (3) Gaseous.

(1) When at or below 32° F. (or 0° C.) it forms a solid, and is known as ice.

(2) Between 32° F. and 212° F. (or 100° C.), if the atmospheric pressure is normal, it exists as a liquid, and is called water.

(3) At and above a temperature of 212° F., and under normal atmospheric pressure, it is a gaseous vapour known as steam.

Water in the first state, viz. ice, is the most dangerous in its relation to hot-water systems, and, unless proper precautions are taken, may be responsible for accidents attended with fatal consequences.

Expansion and Contraction of Water.—If a quantity of ice is subjected to sufficient heat, it will be converted into water, and if the experiment is carefully carried out, it will be observed that the volume of the water is only about $\frac{10}{11}$ of its volume when in the solid state, ice; conversely, if the water is again changed to a solid by extracting the heat, its volume will be increased by about $\frac{1}{10}$. In other words, when water is converted into ice, expansion takes place, and its volume is increased in the proportion above stated.

If after melting a quantity of ice (without raising the temperature above 32° F.) we place the water thus obtained in a glass flask, provided with a rubber stopper through which a piece of $\frac{1}{4}$-in. diameter glass tube about 2 ft. long is passed, with a thermometer projecting downwards into the flask, as shown in fig. 361, so that the water stands in the glass tube about 3 in. above the level of the rubber stopper, and if heat from a Bunsen burner is applied to the flask, it will be observed that, as the temperature

increases, the level of the water in the glass tube is lowered until the thermometer registers a temperature of 39·2° F. This lowering of the water-level is due to two causes: first, the reduction in volume of the water by contraction; second, the expansion of the glass flask, which slightly increases its capacity. On further application of heat, the water will commence to rise in the glass tube as the temperature is increased, until it reaches boiling-point temperature, 212° F.

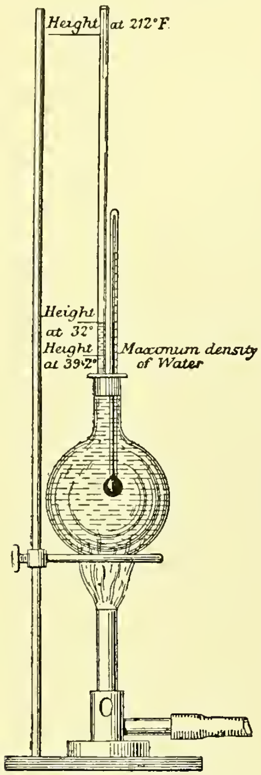


Fig. 361.—Expansion of Water

If for this experiment the glass tube is graduated, and careful observation made during the progress of the experiment, it will be noticed that the increase in height of the water-level in the glass tube is not directly proportionate to the increase in temperature, ranging from 39·2° F. to 212° F.; that is to say, that water, when its temperature is raised from 39·2° F. to 212° F., does not expand an equal amount for each degree of increase in temperature. The increase in volume recorded by the graduated glass tube will not be accurate, owing to the expansion of the glass vessel and the tube itself, the actual increase being slightly larger than the registered amount.

The above experiment proves that when the temperature of water is raised from 32° F. to 39·2° F. the water contracts, and from 39·2° F. to 212° F. it expands. The temperature at which a given weight of water occupies the least space is known as the *temperature of maximum density,* which is 39·2° F., or 4° C. The diagram (fig. 362) shows the expansion of water from the point of maximum density to freezing- and boiling-points.

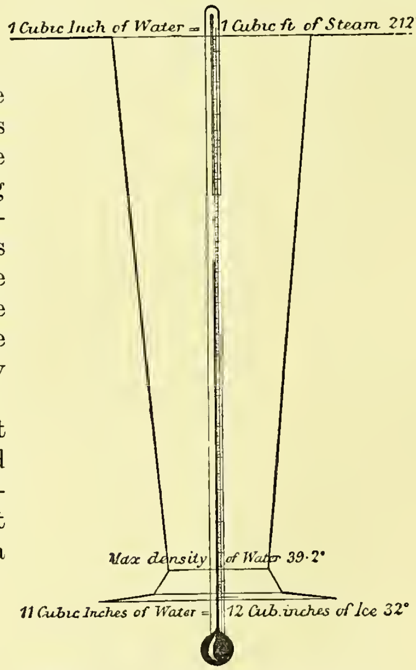


Fig. 362.—Diagram showing the Expansion of Water

Pressure of Hot Water.—The pressure of hot water in a pipe or vessel freely open to the atmosphere at one or more points is less than that which would be produced by the same head of cold water, as the density of hot water is less than that of cold. But when water is heated in closed vessels the conditions are materially altered. If in a hot-water system, the pipes

of which are blocked with ice, the fire is kept burning under the boiler, the pressure rapidly increases owing to the tendency of the water to produce steam and also to expand as the temperature rises. It has been calculated that a pressure of 140 atmospheres (upwards of 2000 lb. per square inch) would be required to prevent the expansion of water when the temperature is raised from 4° C. to 14° C. (39·2° F. to 58·2° F.). In a hot-water system blocked as described above, the boiler would burst or bulge long before the normal boiling-point of the water was reached, if the temperature of the water in the boiler was low when the fire was lighted. The amount of expansion from 39·2° F. to 58·2° F. is only one-fifth of that which takes place under normal conditions when the temperature is raised from 58·2° F. to 86° F., and only one-thirty-ninth part of that due to a rise of temperature from 58·2° to 176° F. It would obviously be impossible to make all boilers and pipes strong enough to resist the enormous pressures thus produced, and safety valves are therefore provided to relieve the pressure if, owing to accidental circumstances, it rises above a certain amount. In every hermetically sealed high-pressure heating system an air vessel is fitted, so that the expansion of the water due to a rise in temperature is relieved by compressing the air. One volume of water at 39·4° F. increases to 1·043 volumes at 212° F.

Steam.—If heat is applied to water at 212° F., the water is gradually converted into steam, with an enormous increase in volume, *one cubic inch* of water being converted into *one cubic foot* of steam (approximately), at normal atmospheric pressure and without an increase in temperature above the boiling-point.

Latent Heat.—If a quantity of pounded ice at a temperature of 32° F. is placed in a vessel and held over the flame of a spirit lamp or Bunsen burner, heat passes rapidly into the ice, and melts it; but a thermometer resting in this mixture shows no tendency to rise, but will remain at 32° until all the ice has disappeared.

What, then, has become of the heat that was required to melt the ice? This question was first investigated and answered by Dr. Black of Glasgow about 1760 in the following way. One pound of water and the same weight of ice, both at 32° F., were placed in separate vessels and suspended in a chamber, which was kept at a temperature as nearly uniform as possible At the end of half an hour the temperature of the water had risen to 39·2°, but it was ten and a half hours before the ice, which had melted in the meantime, reached that temperature. It was reasonably assumed that the ice received the same amount of heat in a given time as the water, namely, $39{\cdot}2 - 32 = 7{\cdot}2$ heat-units[1] per half-hour. The total number of heat-units required to convert the ice into water and raise its temperature to 39·2° F. was, therefore, $7{\cdot}2 \times 2 \times 10\frac{1}{2} = 151{\cdot}2$ heat-units; deducting from this 7·2 units (the amount required to raise the water from 32° to 39·2° F.), the number of heat-units required to convert the ice into water would appear to be $151{\cdot}2 - 7{\cdot}2 = 144$. More accurate observations have fixed the number at 142·65.

[1] A British heat unit is the amount of heat required to raise the temperature of 1 lb. of water at 60° F. one degree.

Thus it may be said that it requires 142·65 times as much heat to convert a given weight of ice at 32° F. into water at the same temperature as is necessary to raise the temperature of an equal weight of water 1° F. The heat which is lost to thermometric measurement during the conversion of ice into water—viz., 142·65 heat-units per pound—is spoken of as *Latent Heat*, and the same quantity has to be released when the pound of water at 32° F. is converted into ice.

If 1 lb. of water is heated to boiling-point (212° F.) at normal atmospheric pressure, and the application of heat continued, the water will be converted into steam at the same temperature; and it has been determined by experiment that water at boiling-point requires 966 heat-units to bring about this change. These heat-units, though lost to thermometric measurement, are given out when the steam condenses, *i.e.* returns to the form of water. The "latent heat of steam" may therefore be stated as 966; that is to say, to convert a given quantity of water at 212° F. into steam at the same temperature it requires 966 times the quantity of heat needed to raise the temperature of an equal weight of water through 1° F.

This fact makes steam a valuable medium for heating water, as 1 lb. of steam at 212° F., if condensed to water at the same temperature, would give out sufficient heat to raise the temperature of 5 lb. of water from 32° F. to 212° F.

Conduction of Heat.—Ice is a bad conductor of heat, as also is water, and this, together with the fact that a great amount of heat is necessary to melt the former, affords an explanation of those boiler-explosions which take place one or more hours after the fire has been lighted, the ice in the boiler melted, and the temperature of the water in the boiler raised to a height considerably above boiling-point (owing to its being enclosed and under pressure). After explosions of this kind the circulating-pipes have been examined and found choked with ice, which the heated water in the boiler was not able to affect, owing to the non-conductivity of the ice.

If a large test-tube is filled to three-quarters of its capacity with water, and the flame of a Bunsen burner held under the side of the tube, inclining at a convenient angle, the water near the surface will soon begin to boil; but if a thermometer is placed inside the tube, with the bulb at the bottom of the tube, and carefully observed, it will be seen that the lower stratum of water, clear of the heat from the Bunsen, is not affected by the heat for a considerable time, although the top stratum of water is being converted into steam. This proves the low conductivity of water.

Convection.—If a large beaker, three-fourths full of water, and containing a small quantity of fine saw-dust, is placed on a tripod, and the flame from a Bunsen burner allowed to play on one side of the bottom of it, the water in immediate contact with that portion of the beaker receiving the greatest amount of heat begins to ascend, as indicated by the movements of the saw-dust. This action will be more readily understood by reference to fig. 363, where it will be seen by the indicating arrows that, after rising to the surface by a semicircular motion, the currents thus set up descend on the opposite side of the beaker. It has been previously explained that, from the temperature of maximum density to boiling-point, water expands,

and consequently becomes lighter, bulk for bulk, than colder water. This explains the direction of the currents in the beaker: *the warmer particles of water are displaced by the colder and heavier particles, causing the former to rise to the highest point* of the water-compass in the beaker. This action is known as *Convection,* and the currents above described as *convective currents.* This is the principle which underlies all systems for domestic hot-water supply purposes.

If a piece of glass tube, bent in the form of the letter U, is attached to a stand, and filled with water to a height 3 in. below the top, it will be noticed that the water rests at equal heights in each leg of the tube; but after applying heat from the flame of a Bunsen burner to one leg of the tube until the water in it is raised almost to boiling-point (fig. 364), the water in this leg of the tube stands at a higher

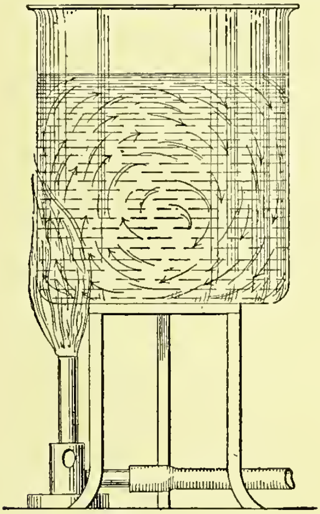


Fig. 363.—Convective Currents

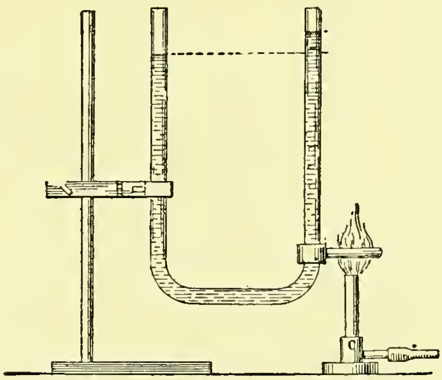


Fig. 364.—Unequal Heights of Cold- and Hot-water Columns

level than the water in the other leg. This difference in level is due to the greater weight of a column of cold water compared with an equal column of warmer water.

The circulation of hot and cold water may be clearly demonstrated by an arrangement of glass apparatus (fig. 365), consisting of an inverted gas-jar and a litre-flask, connected together by two glass tubes, which are made watertight in the jar and flask by india-rubber stoppers. After charging the apparatus with water, the portion in the jar at (*a*) should be coloured with methylene blue or any distinguishing soluble colour. The tube marked (*b*) leaves the top of the flask and projects inside the jar about half-way, while the tube (*c*) begins at a point about 2 in. above the bottom of the flask, and is carried to the mouth of the jar, and not beyond that point. If heat is applied to the bottom of the flask, convective currents are set up, and the water rises, by reason of the displacement caused by the colder water, and passes through the highest outlet, which is the tube (*b*), into the jar above, its place being taken by the coloured water, which passes down (*c*), and is seen diffusing in the water at the bottom of the flask, when it becomes heated and passes in turn through

(*b*). This action goes on until all the water in the apparatus is coloured and heated to practically the same temperature.

Chemical Properties of Water.—No such substance as pure water exists in nature, and water chemically prepared, either by the explosion of the two gases, Hydrogen and Oxygen, or by distillation, does not remain absolutely pure, owing to its solvent action upon almost every substance with which it is brought into contact.

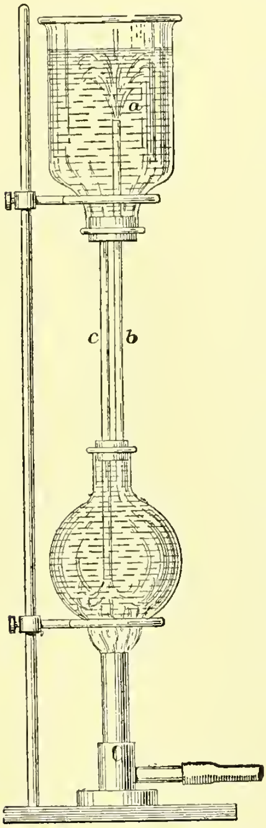


Fig. 365.—Apparatus showing Simple Circulation

If a beaker of freshly-distilled water is left exposed to the air for a number of hours, the water will absorb a quantity of the air, the amount depending upon (*a*) the temperature of the water, (*b*) the pressure of the atmosphere. This fact may be readily proved by the apparatus shown in fig. 366. If the water, after exposure, is poured into the flask (*a*), entirely filling it, and is then heated by the flame, after a few moments air-bubbles will be observed passing from the flask, up the tube (*b*), into the inverted jar (*c*), and gradually displacing the water which it contains; by this means all the air driven off will accumulate in the top of the jar (*c*).

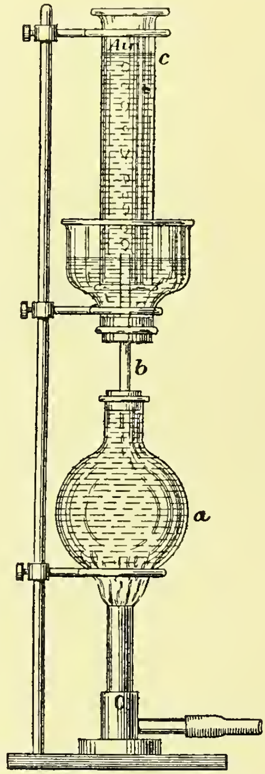


Fig. 366.—Apparatus showing Presence of Air in Water

It may now be stated that water has the power to dissolve or absorb atmospheric air and other gases.

The experiment described above proves also that cold water will absorb a greater quantity of air than warm water, and also that as the temperature of water increases the air which it contains is gradually given off, especially at temperatures above 120° F. This fact requires careful consideration when arranging hot-water systems; otherwise failure and disappointment will occur.

Hardness of Water.—The power of water to dissolve saline matters has often a detrimental effect, and sometimes a disastrous one, upon systems of domestic hot-water supply. The dissolved salts are mainly the carbonates and sulphates of lime and magnesia, which are obtained during the passage of rainwater, either over the surface of the ground or through strata containing the above salts, to an underground source of supply, such as wells

or bore-holes. The sulphates, when present in small quantities, are not detrimental in any way except that they increase the hardness of the water; they are not deposited in the boilers or pipes.

The opposite obtains in the case of the carbonates, particularly the carbonate of lime, which is dissolved in the following manner:—During the passage of the rain through the atmosphere, some of the carbon dioxide (CO_2) always present in atmospheric air, is absorbed by the water, and the quantity of carbon dioxide is added to when the water passes over or through ground containing decaying organic matter. The water thus charged with CO_2 dissolves the carbonate of lime ($CaCO_3$) contained in various strata, and, uniting with it, holds it in solution in the water in the form of a bicarbonate. Thus,

$$\underset{\text{(Water)}}{H_2O} + \underset{\text{(Carbon dioxide)}}{CO_2} + \underset{\text{(Carbonate of lime)}}{CaCO_3} = \underset{\text{(Bicarbonate of lime)}}{Ca(HCO_3)_2}.$$

Carbonate of lime is practically insoluble in pure water; as will be seen by the above equation, its solvency in water is due to the presence of CO_2.

The compound thus formed is not very stable, as the water containing dissolved bicarbonate of lime, if heated, gives off the CO_2 (or a portion of it) which holds the lime in solution, whereupon some of the carbonate of lime is precipitated in the form of a powder. This powder is deposited in the boiler, pipes, and cylinder of hot-water supply systems, and often causes considerable expense and trouble.

Where the quantity of lime held in solution is excessive, the water proves unsuitable for domestic purposes, and efforts are occasionally made to reduce the total hardness.

Temporary and Permanent Hardness.—Hardness is either *temporary* or *permanent*. The former is due to the carbonates of lime and magnesia principally, and may be removed by boiling; but the latter is due to the sulphates of lime and magnesia, and is unaffected by boiling. Hardness is measured in degrees per gallon; water containing 7 degrees of hardness (*i.e.* 7 grains of lime per gallon) and upwards is classed as "hard water", and water containing less than 7 degrees is known as "soft water".

Water-softening.—Clarke's process[1] for removing temporary hardness without boiling the water consists in adding milk of lime, $Ca(HO)_2$, to the water; the lime (CaO) thus added combines with the CO_2, which is holding the carbonate of lime in solution, and forms a second quantity of carbonate of lime, which causes a double precipitation, *i.e.* of the lime added and that already in solution. The chemical equation is as follows:—

$$\underset{\text{(Bicarbonate of lime)}}{Ca(HCO_3)_2} + \underset{\text{(Lime)}}{CaO} = \underset{\text{(Insoluble carbonate of lime)}}{2\,CaCO_3} + \underset{\text{(Water)}}{H_2O}$$

Corrosion.—Pure water in the presence of air, or containing dissolved air, acts very rapidly upon iron, and this factor, if not considered when deciding upon the material to be used for pipes, cylinders, and boilers, will cause trouble. The oxide of iron thus formed is rapidly dissolved and finally precipitated upon the bottom of the boiler and in the pipes in a

[1] For descriptions of various processes, see Section V, Chap. XII.

finely-divided state. When any abnormal disturbance of the water in the system takes place, such as may be caused by the quick discharge from two or more taps, or the raising of the temperature of the water to boiling-point, the rust deposited is taken up by the water, and imparts to it a decided red colour, which renders it unfit for domestic use; moreover, the life of the iron parts of the system is considerably reduced. Wrought iron is acted upon and corroded by water far more speedily than cast iron.

When two metals are in contact with each other in the presence of water of a slightly acid character, a galvanic action is generally set up, which gradually destroys contact between the metals, especially in cases where the salts formed are dissolved by the water, leaving exposed to continuous action the surface of the metals in contact with each other. This action is considerably increased if the temperature of the water is raised. A striking illustration of this is often shown in hot-water systems with lead pipes. The wiped plumbing joints which are used for jointing lead to lead or brass, are often found to be defective, and on close examination it is discovered that the surface of the brass or lead (originally tinned during or before the making of the joint) is completely devoid of any tinning owing to galvanic action.

The solvent action of waters of a slightly acid character upon lead is considerably enhanced when the water is increased in temperature. It is therefore totally unsafe for such water to be drawn for drinking purposes from the hot-water supply system. Cases of lead-poisoning have resulted in several instances from this cause.

CHAPTER II

SIDE BOILERS, THE TANK SYSTEM, AND THE CYLINDER SYSTEM

Side Boilers.—One of the simplest arrangements for the supply of hot water, and one which obtains at the present time in some country districts, consists of a boiler, usually of large capacity and L-shaped, which is fixed at the back or side of the kitchen fire-grate. Provision for an automatic supply of cold water is made by connecting the boiler by means of a pipe to a small cistern (usually having a supply controlled by a ball valve) fixed at the same level as the boiler; a draw-off tap is generally provided in the front of the range, and one part of the boiler is accessible by means of a lid. This arrangement is fairly satisfactory where not more than one or two gallons of hot water are required at one time, but it cannot be recommended for general adoption, owing to the immediate mixing of hot and cold water

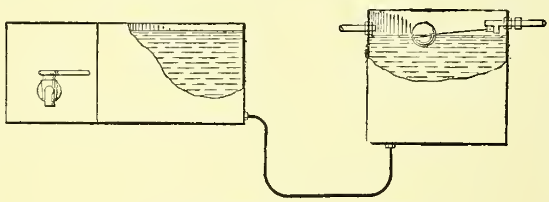


Fig. 367.—Kitchen-range Side Boiler

together when drawing off hot water, and the very limited quantity stored, and the fact that all the hot water must be carried by hand to wherever it is required. Fig. 367 shows the arrangement of the boiler and cistern.

A modified form of this system consists of an entirely enclosed boiler supplied by a pipe from a cistern fixed at a higher level, (say) near the ceiling of the kitchen, as shown in fig. 368. An expansion or air pipe is taken from the boiler, and terminates directly over the supply cistern; from this pipe branches are taken to supply the sink, lavatory, &c. In this system no advantage is taken of the physical property of water, which permits storage of large quantities of hot water at advantageous points, some distance from and above the source of heat, *i.e.* the kitchen fire; but the whole of the heated water is stored in the boiler; therefore the supply will be limited to the capacity of the boiler, which rarely exceeds 10 or 12 gal. For general use this system is little better than that previously mentioned, the only extra advantage being that the hot water may be delivered by pipes at any point *above* the boiler and *below* the cistern.

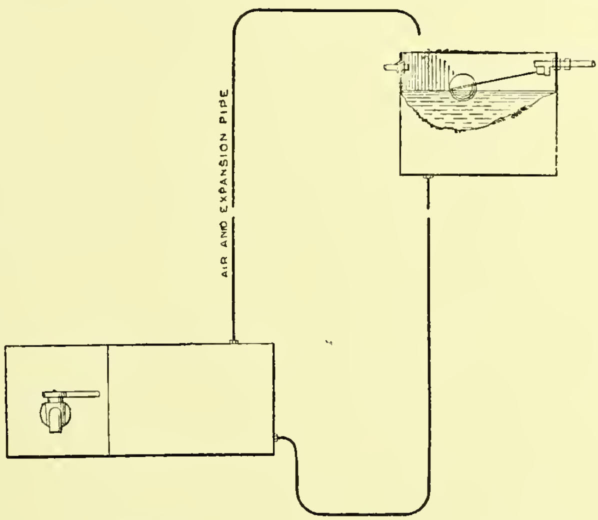


Fig. 368.—Kitchen-range Side Boiler with Cistern at a Higher Level

The Tank System.—In the tank system advantage is taken of the physical property which water possesses, of expanding when heated, to procure a flow of heated water by means of a pipe from the boiler to a tank fixed at a high level; from this tank a second pipe is led to the boiler, down which the cold water passes, displacing the warmer water, and constantly forcing it up to the highest point in the tank, thus setting up a circulation which is maintained as long as there is any difference in temperature between the water in the boiler and that in the tank, provided the water in the boiler has the higher temperature.

One type of this system is shown in fig. 369. The hot-water tank A is fixed in a high part of the house, and supplied from a separate cold-water tank B, fixed on the same level, and connected to it by the dip pipe C. The bend in C prevents the hot water in the tank A from passing into B. The pipe D leaves the boiler at the top, and projects into the tank about 1 ft. above the bottom; this constitutes the *flow pipe*, along which the hot water travels from the boiler to the tank. The object of the projection of the pipe above the bottom of the tank is to deliver the hot water at a high level into the tank, and so to provide a quantity of hot water for use in the

top portion of the tank before warming the whole of the contents, a condition which would obtain if the pipe D terminated at the bottom of the tank. The *return pipe* H is connected to the tank and boiler into or near the bottom of each, and down it the colder water passes from the tank to the boiler.

In some cases the flow pipe is tapped by **branches,** which supply the hot water to the various fittings, as shown at E; but this arrangement is by no means a commendable one, for several reasons: first, it is possible to empty the hot- and cold-water tanks during the stoppage of the supply to the cold-water tank, and this may result in a damaged boiler, owing to the discharge into it of cold water when the supply is resumed, the water in the circulating pipes and boiler in the meantime having been evaporated, and the front portion of the boiler heated to redness; second, it is possible to draw lukewarm water, even when the tank contains very hot water (especially if a moderate quantity is drawn), owing to the water from the cold-supply tank passing as a separate stratum across the bottom of the hot-water tank, down the return pipe, and through the boiler to the point of delivery before it has had time to become heated; at the same time there may be a flow of hot water from the "hot tank" down the flow pipe to the point of delivery. Thus, instead of hot water, a mixture of hot and cold is obtained. This disadvantage may be obviated by inserting a pipe, as shown by dotted lines at F, projecting into the tank A, to act as a draw-off pipe, and connecting any branches to it. With this arrangement the cisterns cannot be emptied when the cold supply is stopped, and any hot water which the tank contains will, owing to its lightness, be in the highest part of the tank, and available for supply without the risk of a mixture of hot and cold taking place during the drawing-off.

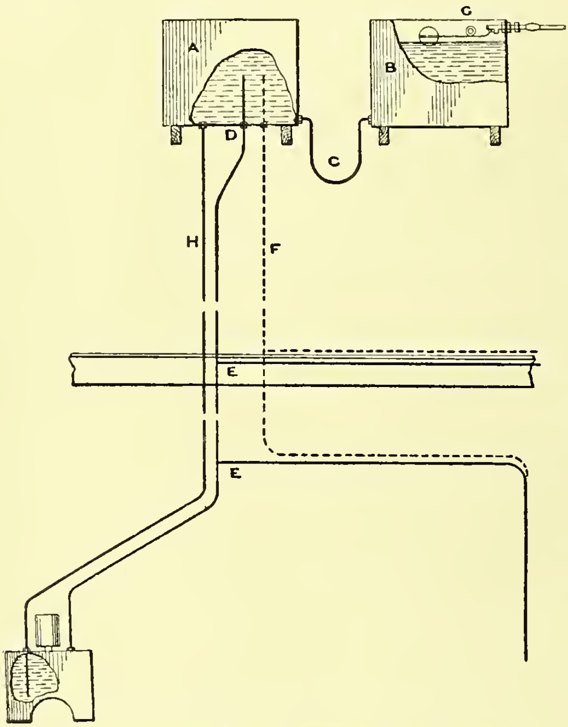


Fig. 369.—An Example of the Tank System with Open Tank

The overflow pipe G, connected to the cold-water tank, should be fixed several inches above the normal water level, to allow for the increase in volume of the water in the hot tank and boiler when heated. The overflow

is merely intended to act as a warning pipe to indicate any defect in the ball cock, which would, if not attended to, cause waste and possibly damage, and it should be arranged to discharge in some prominent place, so that the defect may be at once apparent.

Another example of the tank system is shown in fig. 370. The hot-water tank in this case is fixed several feet below the cold-water cistern, and consequently requires to be entirely enclosed. Provision is made for the escape of air and steam by a pipe connected to the top of the tank at A, the end of which may either terminate over the cold-supply cistern, or be carried through the roof and bent over as shown by dotted lines at B. The draw-off pipe is connected to the top of the tank at C; and, as the tank is under pressure, all the hot water stored in it can be drawn off, but at the same time, of course, an equal quantity of cooler water passes into the circulation. The flow and return pipes are arranged as in the previous type; the return pipe discharges its contents about $2\frac{1}{2}$ in. above the bottom of the boiler.

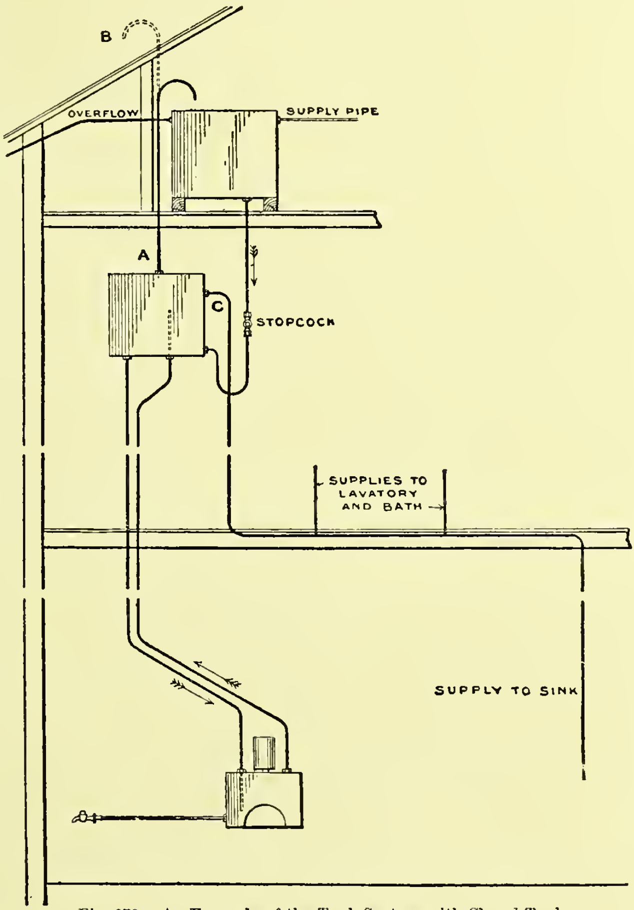


Fig. 370.—An Example of the Tank System with Closed Tank

The tank system is very rarely adopted in new work, as it has **many disadvantages.** The length of circulating pipes is great, owing to the hot-water tank being fixed in a high part of the house, and consequently there is a considerable amount of friction, which retards the flow of the water to and from the boiler; there is also much loss of heat by radiation from the long circulating pipes, unless these are covered with non-conducting material. The tanks are usually fixed in some inaccessible place in the roof of the house, or near the ceiling, to give the requisite head for supplying the fittings fixed on the highest floor, and as a rule no provision is made for preventing

loss of heat by radiation from the hot-water tank; in cold weather the loss by radiation is by no means small. The tanks are often unprovided with a cover of any description, and dust, soot, and other impurities enter the tanks and foul the water. The steam or watery vapour arising from the open tank proves objectionable, by condensing, and saturating woodwork, &c., in the vicinity with moisture. In the first-mentioned type it is possible to empty the tanks, with risk of fracturing the boiler.

The only advantage possessed by the tank system is the rapid flow of hot water which can be obtained, owing to the comparative shortness of the pipe delivering it, from the source of supply.

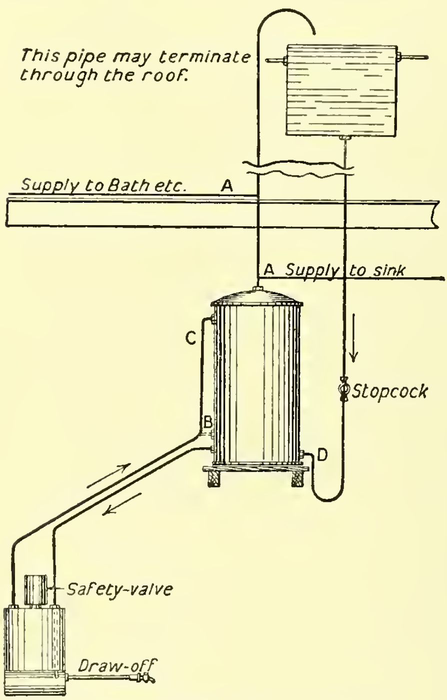
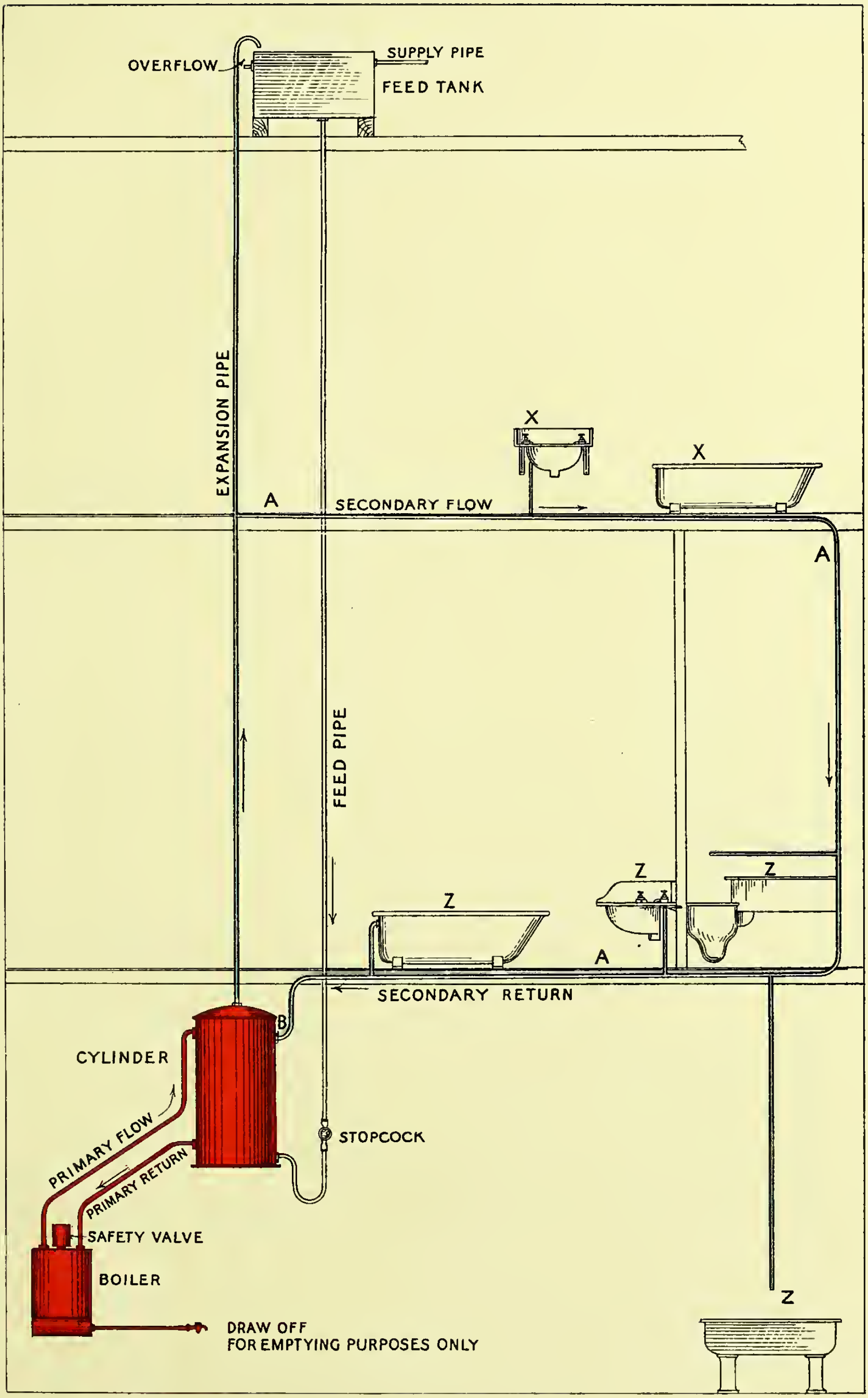


Fig. 371.—Cylinder System: Cylinder near Boiler

The Cylinder System is an improvement on the tank system in several ways. The hot-water reservoir is cylindrical, and is fixed as conveniently near the boiler as possible, while the tank for supplying the reservoir is fixed in a high part of the house, above the level of the highest fitting receiving a supply of hot water.

Fig. 371 shows **a simple type of cylinder system** suitable for a cottage. The cylinder is fixed near the boiler, thus reducing the length of the circulating pipes, and obtaining a more rapid circulation of water between the boiler and cylinder. The reduction in the length of the pipes is also an advantage where these pipes are in lead, as it reduces the amount of expansion and contraction, due to the changes of temperature of the water passing through them. This is especially the case with the return pipe, down which the cold water flows from the supply tank, after passing through the cylinder.

The *expansion pipe* is taken from the top of the cylinder, and is carried up to a point well above the cold-water tank. From this pipe branches to the various fittings are taken at a convenient height, as shown at A A, fig. 371. By this arrangement hot water can be obtained so long as the cylinder contains any, and it is impossible under normal conditions to empty the cylinder during the stoppage of the cold-water supply. On no account should hot-water supplies be taken from circulating pipes, as the adoption of such a course would entail the disadvantage previously mentioned in connection with the tank system, namely, that of emptying the cylinder, besides rendering it impossible to obtain hot water from such connections at all times, owing to the cold water passing through the bottom portion



HOT-WATER SERVICES

Cylinder System with Cylinder on Ground Floor

of the cylinder, down the return pipe, and out through the branch in the flow pipe, without being affected by the heat of the fire to any appreciable extent during its passage through the boiler.

The position of the **connections of the flow and return pipes** to the cylinder requires careful consideration. The usual plan is to connect the return pipe to the cylinder about 6 in. from the bottom, and the flow pipe (bringing the heated water from the boiler) about a foot above the bottom, as shown at B, fig. 371. With this arrangement it is necessary to raise the temperature of the whole of the water in the cylinder above the flow-pipe connection, before hot water can be drawn from the cylinder. This is a great disadvantage, especially where moderate quantities of hot water are required soon after the fire has been lighted. To minimize this disadvantage the flow pipe should enter the cylinder, as shown at C, about 9 in. from the top, or be turned up inside to the same height, thereby discharging the heated water near the top of the cylinder, and permitting the accumulation of a small quantity of hot water soon after heat is applied to the boiler.

The cold supply to the cylinder may be either taken in at the bottom, or connected to the side of the cylinder, as D; a dip or trap should be formed at this point, to prevent what is known as a local circulation taking place between the cold-water cistern and the cylinder. This pipe should be used solely for supplying the cylinder with cold water, and on no account should it be used for a cold-water supply to any fittings. The sectional area of this pipe should be at least one and a half times the area of the cross section of the hot-water supply pipes, which are branched from the air or expansion pipe; otherwise the delivery of hot water will be greatly retarded, as the rate of flow depends upon the volume and velocity of the water entering the cylinder through the cold-supply pipe. A full-way stop cock should be fixed near the cylinder, to shut off the supply in case of repairs, &c.

The termination of the expansion pipe by bending it over the cistern about 2 ft. above it is not always a commendable practice, especially where large fires are kept, and where the cold-water supply to the various fittings in the house is obtained from the same tank as the cold supply to the cylinder, for large quantities of steam are generated, and, while escaping through the air pipe, the steam forces volumes of water before it into the cold-water tank, which increase the temperature of the water in the tank, so that warm instead of cold water is drawn at the cold-water taps. If the second method of carrying the air pipe through the roof is adopted, this disadvantage is entirely eliminated, but during frosty weather there is a likelihood of the end of the pipe becoming frozen over, which may result in the collapse of the cylinder, an explanation of which will be given in the latter portion of this work.

Cylinder on First Floor.—Very frequently the cylinder is fixed in the bath-room, on the first floor, as shown in fig. 372. By this arrangement the bath-room is heated, and, generally speaking, the conditions as regards the temperature of the air, &c., especially in winter time, are safer and more suitable than in a cold situation, besides rendering the room pleasant

for use. The cylinder also provides a very acceptable means of heating for an airing or linen closet. The circulation pipes are necessarily longer, and the cold-supply pipe is shorter, than in the previously-mentioned arrangements; the former being thus a disadvantage, but the latter a gain.

The circulation pipes between the boiler and cylinder are generally known as "**primary circulation pipes**". They are coloured red in Plates XVIII to XXII. In some cases, in large houses, the various fittings supplied with hot water are situated at some distance from the hot-water cylinder, and this necessitates a quantity of cold water being drawn from the hot-water tap before hot water is obtained. This is both inconvenient and wasteful.

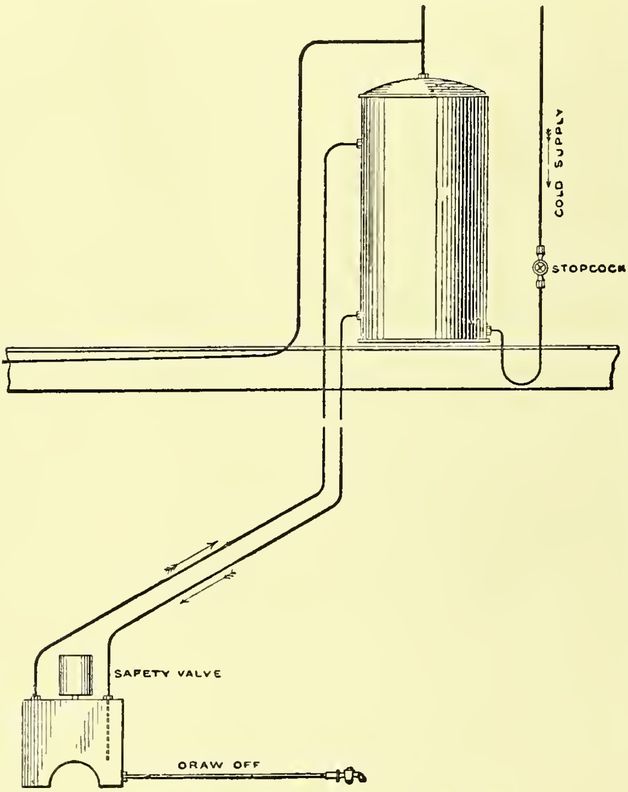


Fig. 372.—Cylinder System: Cylinder on First Floor

To obviate this defect the hot-water supply pipes should be so arranged that an immediate supply of hot water can be obtained on opening the "hot" tap of any fitting. The arrangement by which this is accomplished is known as the "**secondary flow and return**", and consists essentially of a pipe, which is taken from the air or expansion pipe, and, after taking a route which passes all the fittings at a convenient distance, is returned to the cylinder, which it enters about 1 or $1\frac{1}{2}$ ft. from the top; in Plates XVIII to XXII the secondary circulation pipes and branches are coloured blue. In Plate XVIII the "secondary flow", A, is branched out of the air pipe, and is taken past the various fittings shown, and returns to the cylinder at B. Great care is required, when arranging the route for the pipe, to avoid dips or traps. To ensure success, a slight fall from the point where the flow leaves the expansion pipe to its connection, B, to the cylinder should be arranged, so that any steam or air which may be given off from the water can escape through the expansion exit. Dips on this pipe may also stop the secondary circulation entirely by the accumulation

of a body of cold water in the dip, which, being heavier than a corresponding column of hot water, has a tendency to remain there. The route chosen for the secondary flow pipe should, therefore, be carefully considered, with a view to avoiding such defects, as under ordinary conditions the greater part of this pipe has to be laid under the floor boards, with very little fall; if possible a minimum fall of $\frac{1}{8}$ in. per yard should be obtained under floors and similar places.

In many instances which have been brought before the writer's notice the secondary return pipe has been connected to the primary return as shown in Plate XIX, but this is not a satisfactory arrangement. All forces move along the line of least resistance, and flowing water is no exception to the rule. The convective currents in a hot-water system always start at the boiler, and, passing along the primary flow pipe, enter the cylinder,

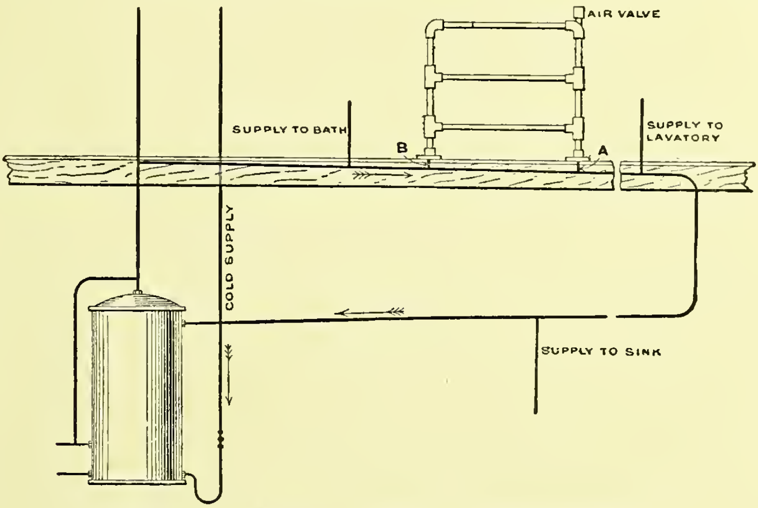


Fig. 373.—Towel Rail and its Connection to the Secondary Circulation

and then rise up the expansion pipe, flow through the secondary circulation back again to the cylinder and boiler; but when a tap is opened on the secondary circulation, the direction of the flow in this part of the system is suspended, and water travels in both directions to the opened tap. If the draw-off takes place near the expansion pipe, as at X (Plate XVIII), the bulk of the water delivered will flow through the expansion pipe, but if any of the taps marked Z are opened, the line of least resistance to the flow is through the cylinder connection B, in the opposite direction to the normal flow; and if this connection is made to the primary return pipe there is a great risk of lukewarm or cold water being drawn. This risk is considerably reduced by connecting the pipe as at B, as the water in that portion of the cylinder will probably be higher in temperature at all times than the water flowing down the return pipe to the boiler. For a secondary circulation below the boiler see fig. 381, p. 29.

Where the boiler is of sufficient capacity, arrangements can be made to warm the air of the bath-room by fixing "coils" or radiators on the secondary

circulation; these are also useful for drying and airing towels, and when specially constructed for this purpose are called *towel rails.* There are two principal methods of connecting them to the circulatory system. The first consists in inserting two connections in the secondary flow—one at each end of the coil, or radiator; the route arranged for this pipe is usually convenient for such connections to be made. This arrangement is shown in fig. 373 and Plate XIX. When the water in the coil is of lower temperature than that in the flow pipe, it falls down the pipe A (fig. 373), and its place is taken by warmer water passing through B; the temperature of the water passing through the radiator is therefore always the same as the water in the secondary flow pipe.

Provision must be made for **the escape of air,** or gases which may be given off by the water during its passage through the radiator. There are several methods of accomplishing this. The simplest consists in screwing a tap or cock into one end of the radiator; this necessitates constant attention to prevent the higher portions of the coil becoming filled with air, which would stop circulation in those parts until the cock is opened and the air escapes.

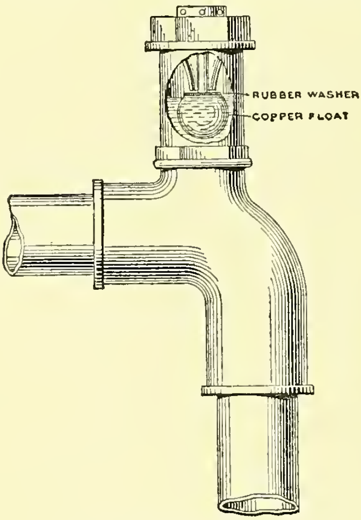
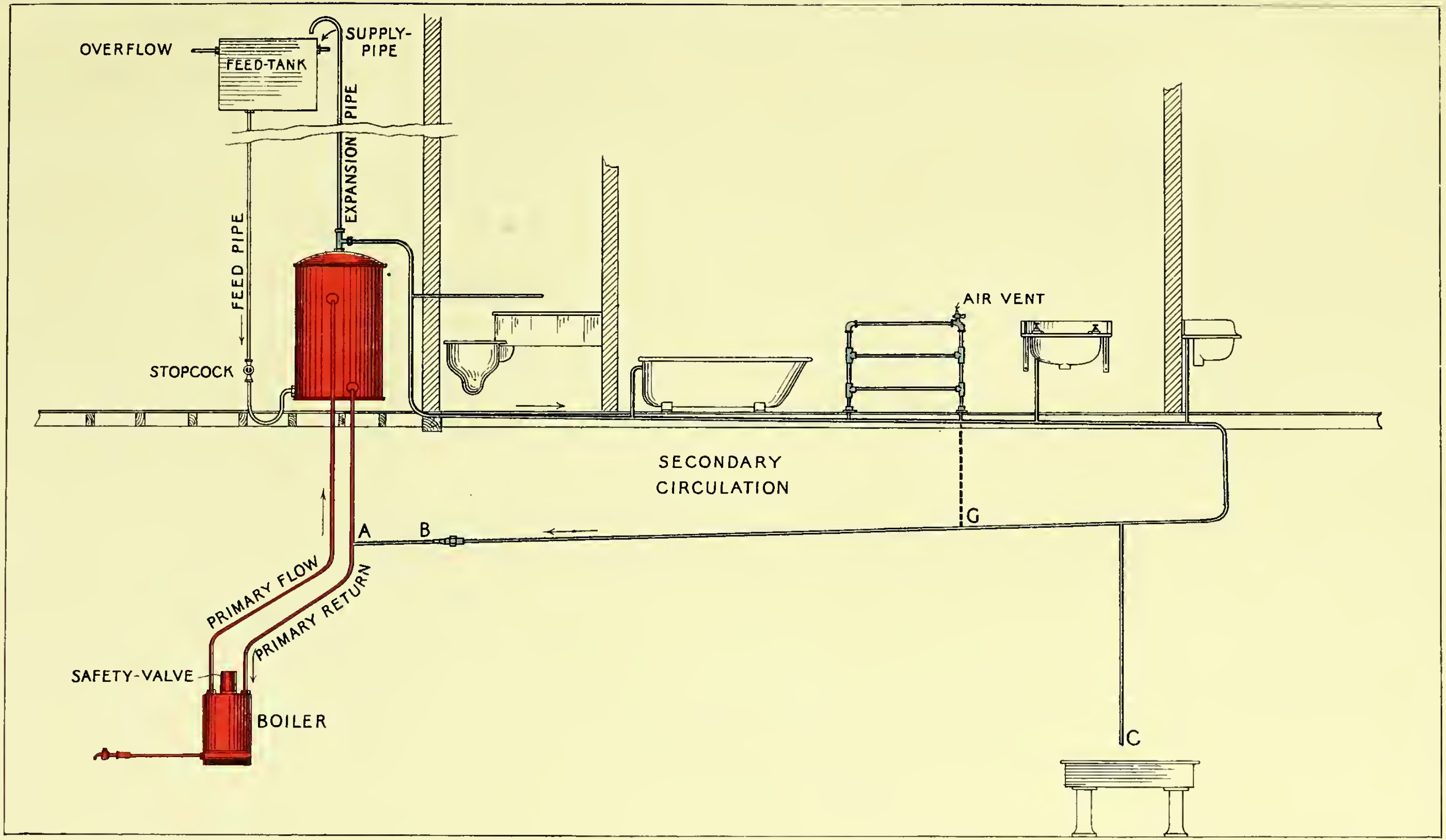


Fig. 374.—Sectional View of Air Valve for Coil or Radiator in Position

A second method, but one which is rarely adopted, consists in taking a lead or brass air pipe, of small diameter, from the highest point of the radiator to some height above the level of the water in the cold-supply cistern. This arrangement is automatic, but where the air pipe has to be laid horizontally in one or more parts of its length, it is not very reliable; moreover, it is generally difficult to adopt.

A third method consists in using an automatic valve, as shown in fig. 374. This has a float so constructed that, when the system is filled, the water raises the float and forces the prepared surface which it possesses at the top against a seating in the upper portion of the valve, and thus prevents the escape of water. When an accumulation of air occurs in the high part of the radiator, it gradually forces the water away from the float, which falls clear of the seating and allows the air to escape, and the water then again forces the valve up to its seating and closes the exit. The disadvantage of these valves is the tendency for grit or small particles of other substances to adhere to the float or seating, and so prevent their being made water-tight, and, as this may occur at any time of the day or night, there is always an element of risk attending their use. A small cock may with advantage be fixed between the air valve and the radiator.

Secondary Circulation with Cylinder on First Floor.—Where the cylinder is fixed on the first floor, a modification is necessitated in the arrangements in connection with the secondary system above described. The secondary



HOT-WATER SERVICES
Cylinder System with Cylinder on First Floor

flow may be connected either to the upper part of the side of the cylinder, or it may be branched from the expansion pipe. The latter method is generally adopted, and is shown in Plate XIX. The secondary circulation, it will be seen, passes through two dressing-rooms to supply lavatory basins fixed in these rooms, and in many cases it is desirable to provide at those points small towel rails connected with the hot circulation; the method of connection previously explained would be found satisfactory. The main disadvantage of this system—namely, the connection of the return of the secondary circulation with the primary return, as shown at A, Plate XIX —was explained on page 17. In addition to this, if the cold supply is shut off, and large quantities of water are drawn from the cylinder at the tap C over the sink—this being lower than the cylinder,—the cylinder would be emptied.

To avoid these defects it is usual to fix a *reflux valve* at B. This permits a flow of water towards the boiler, but when the water attempts to flow from the boiler up the return pipe, the valve closes and prevents the water passing in that direction. This valve is shown in fig. 375; it should, of course, be fixed on the boiler side of the various branches from the secondary circulation, and the valve itself should be quite horizontal.

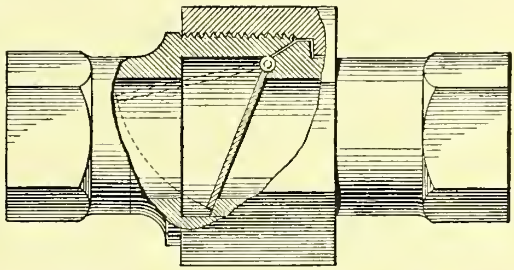


Fig. 375.—Sectional View of Reflux Valve for Use on Secondary Circulation

This arrangement is not so satisfactory as the previous one, where the cylinder is fixed near the boiler. There is always some risk attending the use of a reflux valve; its seating may become rough, or the valve may stick in one position, and throw the entire secondary circulation out of action.

An alternative method of connecting towel rails to the secondary circulation is shown in Plate XIX by the dotted line G, which shows the return or second connection taken to another part of the circulation by a vertical pipe. Where this arrangement can be adopted a more rapid circulation through the towel rail takes place, owing to the vertical column of cooled water in G flowing, by its greater density, into the lower part of the secondary return. It has been urged against this method that there is a probability of all the hot water passing through the by-pass formed by the pipe G, and so preventing any circulation in the farther portion of the pipe; but this is scarcely borne out by actual experience, as the water in the farther portion of the system, on cooling, must fall towards the boiler so long as there is any difference in the temperature of the water in the various portions of the pipe.

Cylinder and Tank Compared.—Here the question may be asked, why it is necessary to substitute a cylindrical vessel for the closed rectangular tank. The reason is, that a given circle encloses by its circumference a greater area than any other figure, rectilinear or otherwise, the sum of

whose sides is equal to the circumference of the given circle. If a rectangular tank of the same capacity were substituted for the cylinder, the sides would tend to bulge out, and to assume a spherical shape, with great risk of the angles being fractured; a cylindrical vessel, made from thinner material, would withstand a greater pressure without risk of fracture.

Horizontal Cylinders.—Where space is restricted, it is sometimes found advisable to fix the cylinder on its side; but such a practice is to be deprecated, as there are several objections to it, the principal being that the whole of the water in a cylinder so fixed has to be raised to almost equal temperature before hot water can be obtained. It will be seen that cylinders

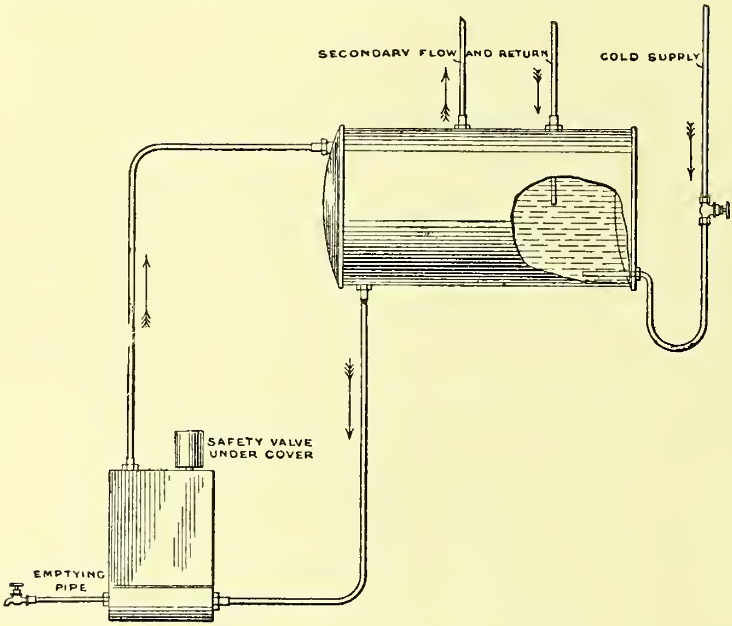


Fig. 376.—Arrangement of Pipes for Cylinder Fixed Horizontally

fixed upright have a decided advantage by the accumulation in the highest part of a moderate quantity of hot water without raising the contents of the lower part to anything like the same temperature.

The horizontal cylinder is also more difficult to fix, and the connections to it involve special treatment. Fig. 376 shows an efficient arrangement. The supply pipe is connected to the cylinder with a bend, turning the flow in the direction of the return pipe; if this precaution is not observed, there will be a great risk of the cold water passing up the hot draw-off pipe when large quantities of hot water are required from the cylinder. The flow pipe from the boiler should enter the cylinder about 6 in. from the top of the nearest end, and the return pipe, as shown, should be taken from the bottom of the cylinder.

In some instances **two cylinders** are fixed on the first floor, one being used as a storage reservoir for hot water required in the pantry and scullery, and the other for storing the hot water required for baths, lava-

tories, &c. This arrangement has the distinct advantage that the hot water necessary for the two purposes mentioned is obtained from separate cylinders, thus preventing possible inconvenience when the requirements in the one part of the house are unusually high. As the hot water in the two cylinders is obtained from one boiler (fig. 377), care should be taken to equalize, as far as possible, the distribution of the hot water by proper arrangement of the pipes to and from the boiler. A horizontal branch taken from a

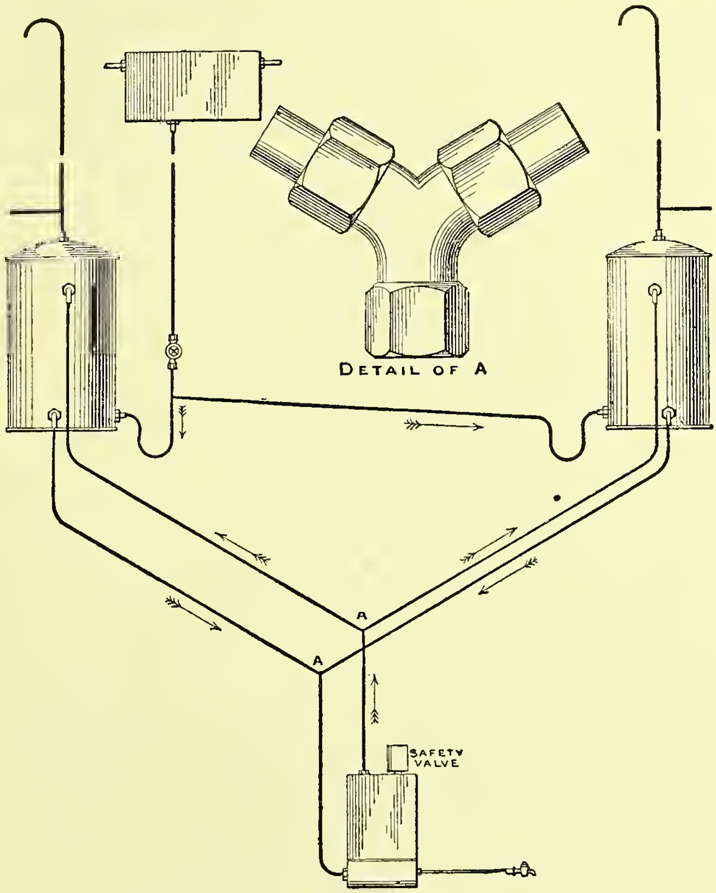


Fig. 377.—Two-cylinder Connection to One Boiler, &c.

vertical pipe should not be permitted under the circumstances. An entirely separate flow and return pipe to each cylinder from the boiler should, if possible, be provided; but if this cannot be conveniently arranged for, **Y**-pieces, as shown in the detail in fig. 377, should be inserted in the flow and return pipes about 2 ft. above the boiler, to direct the convective currents equally in both directions towards and from the separate cylinders.

Another question, which affects the equal distribution of the hot water, is the length and route of the circulation pipes. If one pair is longer and possesses more bends than the other, it is highly probable that the greater friction in the longer circuit would result in the cylinder on that circuit

obtaining a smaller quantity of heated water in a given time than the cylinder on the shorter. This may be minimized by using circulating pipes of slightly increased bore for the longer circuit.

The cold supply is shown entering each cylinder separately by two branches from the main supply, which should be slightly larger than the branches. To prevent the water from one cylinder passing into the other when water is being drawn from either cylinder, a reflux valve could be fixed on one of the branches of the cold supply. The expansion pipes are taken through the roof or turned over the cistern, as previously described.

In **tenement houses** the hot-water supply is sometimes obtained from a single system heated by an independent boiler, and this is often the best and most economical arrangement; but in other cases a separate system, heated by the kitchen-range boiler, is installed in each tenement, one cold-water tank being sometimes used to supply a group of hot-water systems.

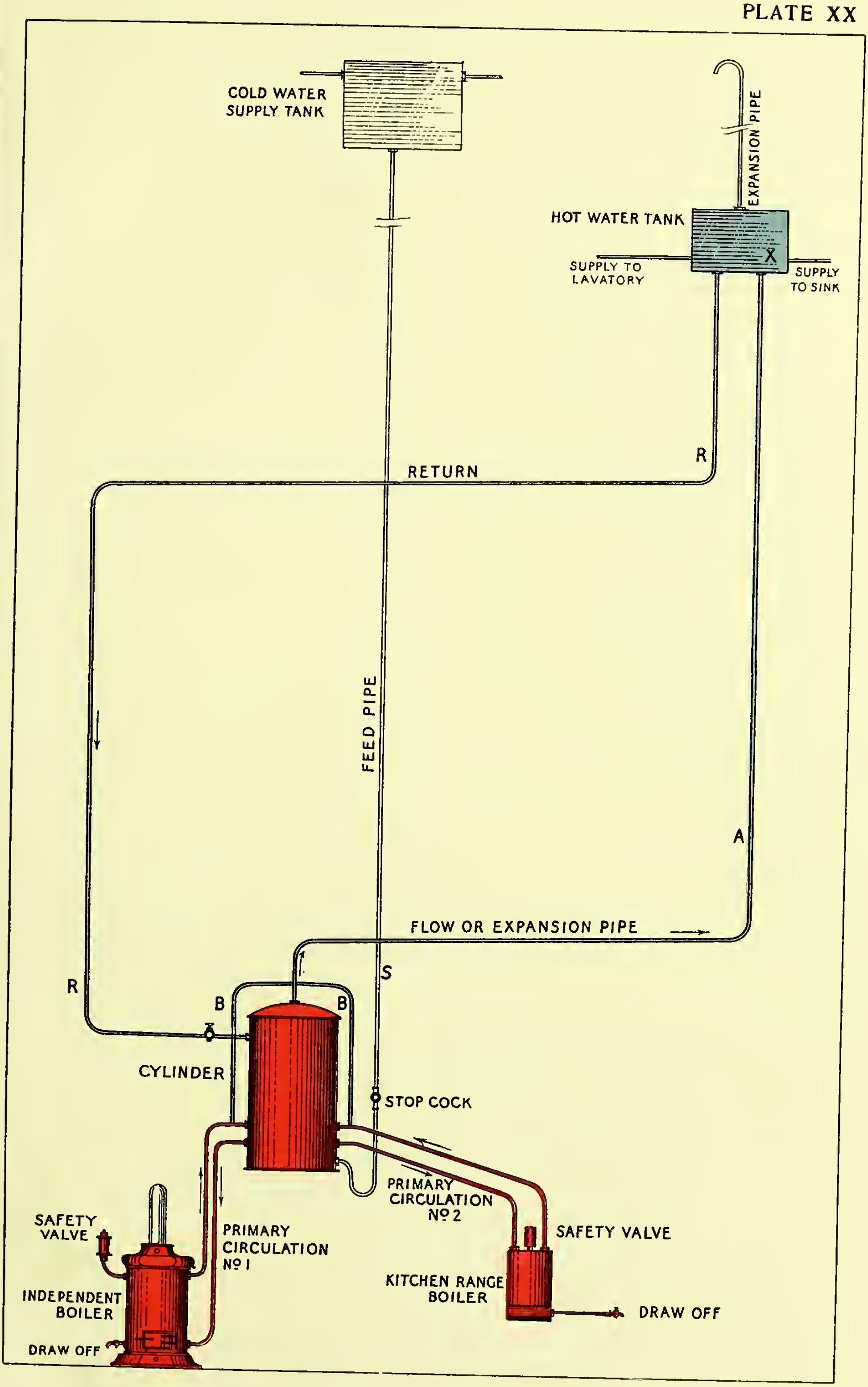
CHAPTER III

THE CYLINDER-AND-TANK SYSTEM

In the previous chapter the arrangements for a simple circulatory system have been discussed, but in large houses, hotels, and public institutions, &c., the questions of **sufficiency and rate of delivery** of hot water call for further consideration. Fittings are fixed in all parts of these buildings, and it is necessary to secure the rapid delivery of hot water at each "hot" tap immediately the tap is opened. Some of the fittings may be considerably more than 100 ft. from the heat-source, and each time hot water is drawn from the system, cold water has to pass down the cold-supply pipe into the cylinder, and force the heated water through the cylinder and the secondary circulation to the exit provided by the open tap. The great amount of friction caused by the passage of the water through such a long length of pipe considerably retards the flow and diminishes the rate of discharge. This is more noticeable when two or more taps are opened at the same time. If one of these is situated on a lower floor than the others, it is very probable that the taps on the upper floors will not afford anything approaching a satisfactory discharge, and in some cases no water will issue at all during the time that water is being drawn at the lower level. Such a condition of affairs could not be tolerated in large buildings where during certain portions of the day large quantities of hot water are required within a few minutes in various parts of the building.

By inserting an extra hot storage reservoir in a convenient place above the highest fitting supplied from the system, and by carefully arranging the pipes in connection with it, hot water may be obtained from any of the taps, so long as the boiler is of sufficient heating capacity to meet the demands made upon it.

There are many variations of this **combined tank-and-cylinder system,**



HOT-WATER SERVICES

Cylinder System with Hot Tank and two Boilers

and much difference of opinion obtains regarding the position of the tanks and cylinders, and the connection and routes of the pipes associated with them. Plate XX shows a simple system with two boilers, suitable for a small hotel or a large private house. The extra storage reservoir X is fixed on the uppermost floor in a part of the building containing several fittings supplied by the hot water in the tank. When water is drawn from the taps on the secondary flow A, the bulk of it comes from the tank X, this being the line of least resistance, and therefore a free and rapid discharge takes place at these taps, which reduces the water level in the hot storage tank. When the taps are closed, the water rises along the secondary flow and return pipes into the tank until equilibrium is restored in the two columns of water.

The secondary flow pipe in this system is the principal supply pipe, most of **the branches** being taken from it to supply the various fittings. The secondary return pipe R also provides supplies to various fittings, and is connected to the cylinder near the top. It will be observed that two pipes are taken directly from the hot storage tank to two fittings fixed at a lower level; this practice ensures a supply to these fittings, irrespective of the demands which may be made at the same moment on the fittings connected with the secondary flow or return pipes.

The secondary flow and return pipes are connected to the bottom of the hot storage tank, and terminate at the same level; this is different from the arrangement which obtains in the case of the hot reservoir of the "tank system", where the flow pipe projects into the tank about 1 ft. above the bottom, in order to prevent cold water passing down it when the taps branched from it are opened. If the flow-pipe in Plate XX projected through the bottom to any appreciable extent, and a large quantity of water was extracted from the branches upon it, it is highly probable that the water level in the tank X would be lowered to the top of the projecting flow pipe, and the water in the tank below that level would not be available; additional water drawn from the taps would have to pass through the cylinder, and consequently the discharge would be greatly retarded.

The secondary flow pipe in this system also acts as **the air pipe** from the cylinder, and therefore, during fixing, care should be taken to obtain a fall towards the cylinder, in order to prevent accumulation of air, which would materially affect the efficiency of the system. The hot-water storage tank must be provided with an air pipe, which should be treated in a similar manner to the air pipe from an ordinary cylinder.

By-passes.—Since the hot water stored in the tank X is mainly called upon, owing to its position, when the draw-off taps are first opened, provision should be made for the water which it contains to be heated before the bulk of the water in the cylinder is raised to the same temperature. This may be arranged by connecting the primary and secondary flow pipes together near the top of the cylinder by means of a pipe of small bore B, which is known as a "by-pass"; this practice is generally followed in combined cylinder-and-tank systems, and sometimes in the simple cylinder system, where this has a secondary circulation. Its advantage is obvious, especially in the combined system, as it permits a flow of heated water to take place

(as soon as heat is applied to the boiler) direct to the hot storage tank, whilst at the same time a portion of the heated water passes into the cylinder, thus rendering a large volume of hot water available in the cylinder and hot storage tank about one hour after the boiler fire has been lighted. The cold supply S is connected to the cylinder in the ordinary manner, which is the best.

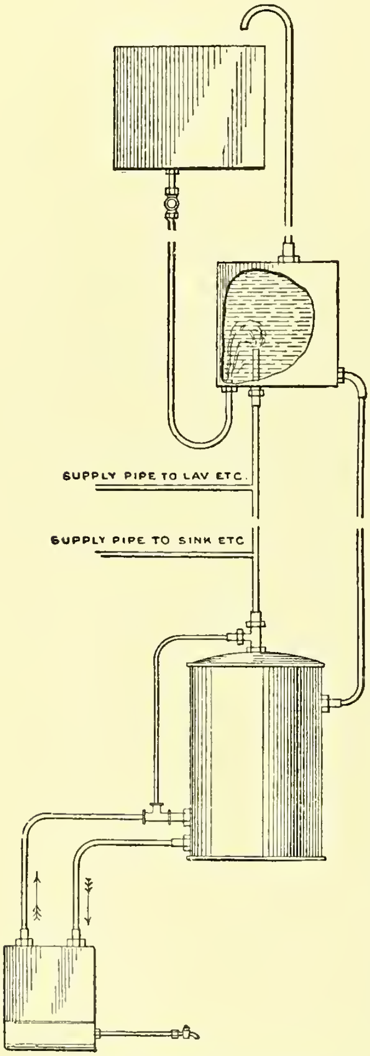
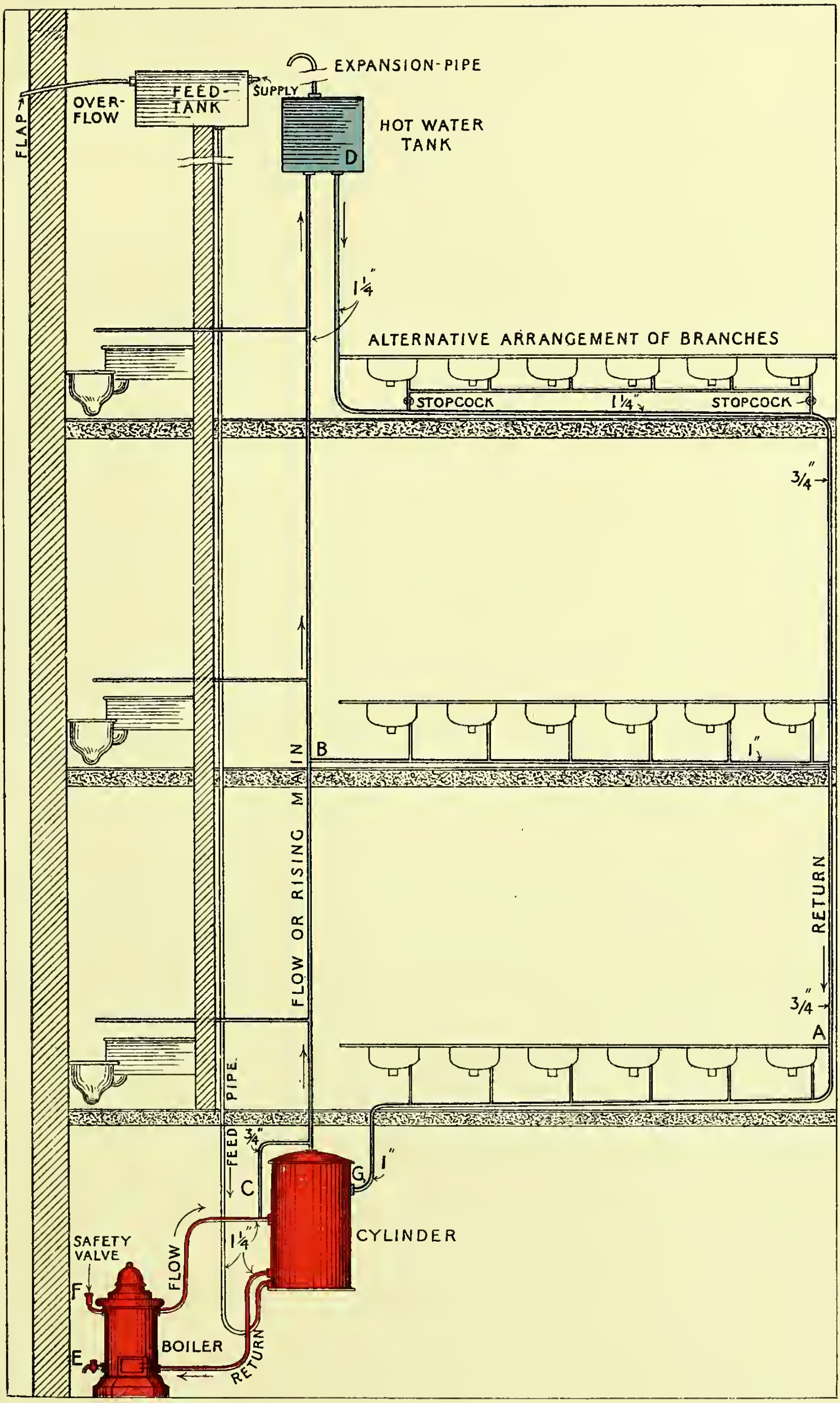


Fig. 378.—Cylinder-and-Tank System with Cold Supply connected to Tank (Faulty Arrangement)

Towel rails are sometimes connected to these systems in the same manner as previously described. Where a number of towel rails are fitted to a hot-water system, the loss of heat by radiation should be borne in mind, and provision made as regards extra boiler capacity to compensate for the loss of heat. It must be distinctly understood that these systems are designed essentially for the supply of hot water, and any supplementary arrangement which may extract a substantial amount of heat from the system, thus affecting its efficiency, should be taken into consideration, and provision made accordingly.

A faulty arrangement (shown in fig. 378) recently came under the writer's notice, where the cold supply is taken into the hot-water storage tank, and the secondary flow projected into this tank to a height about 9 in. above its bottom. It is evident that this arrangement was adopted because it required a shorter length of supply pipe than would have been the case if the pipe had been taken down to the cylinder. Water drawn from the taps on this system was hot for a short time, but the longer it was drawn the cooler it became, until cold water was delivered. This may be explained by reference to the illustration; the cold water from the supply pipe—without forming a lower stratum in the tank, as would be theoretically supposed—flows through the hot water, mingling with it to some extent, and passes down the flow pipe. A connection of this description renders the water in the cylinder almost unavailable for hot supply.

In many **public institutions and suites of offices** in large buildings, the lavatory and other fittings requiring a supply of hot water are situated in a part specially designed and set apart for all sanitary fittings. The hot-



HOT-WATER SERVICES

Cylinder System with Hot Tank and Independent Boiler

water supply is usually provided for by the cylinder-and-tank system, and a boiler, of the "independent" type, is usually fixed in the basement. The demand upon this system at certain periods of the day is very heavy, necessitating provision for adequate storage to meet all requirements, and the sizes of the pipes should also be such that no shortage at the taps on the upper floors will occur when the taps on the lower floors are opened.

Plate XXI shows a suitable arrangement of pipes, tanks, and cylinder for the purpose, and gives the sizes of the pipes calculated to produce the best results. The secondary flow is taken by a 1¼-in. pipe from the cylinder direct to the hot storage tank fixed above the highest range of lavatories, and a similar pipe is taken from the bottom of the tank at D to supply the lavatories on the second floor; this secondary return is carried down in ¾-in. diameter pipe through the other two floors to the point A, and is continued from this point in 1-in. piping and finally connected to the cylinder at C, about 9 in. below the top.

A 1-in. branch, B, is taken from the secondary flow and is connected to the vertical ¾-in. secondary return; the lavatories on the first floor are supplied from this pipe, which has a slight fall from the flow to the return pipe. The housemaid's sink on each floor is supplied by a ¾-in. pipe taken from the 1¼-in. secondary flow pipe, as this arrangement ensures a copious delivery of hot water to these fittings. The by-pass at C provides for the accumulation of a body of hot water in the tank D in a minimum length of time after the fire has been started in the boiler. The cold-supply tank is fixed several feet above the hot-water tank, and provides a supply of water to the apparatus through a 1¼-in. pipe, which is controlled by a full-way stop cock fixed on the vertical run of the pipe, as shown in Plates XVIII and XIX. The primary circulation pipes are as short as possible, and 1¼ in. in diameter, and the boiler is provided with a draw-off cock E and a safety valve F.

The three ranges of lavatories are provided with an ample supply of water from different directions. The supply to the range fixed on the second floor will be derived chiefly from the secondary return pipe, which is connected to the bottom of tank D, whilst the supply to the six lavatories on the first floor will be obtained from the 1¼-in. secondary flow, through the 1 in. branch B, although this will be supplemented under certain conditions by a flow of water through the branch from the ¾-in. vertical secondary return pipe. The lavatories on the ground floor are fed by the 1-in. pipe which forms the continuation of the ¾-in. secondary return to the cylinder; the water drawn at these last lavatories will pass mainly from the cylinder through G, but a certain quantity would sometimes also be delivered through the ¾-in. pipe. In this arrangement the opening of the whole of the taps on the ground floor has no appreciable effect upon the supply to the lavatories on the first and second floors.

As the tank D is fixed several feet below the cold-water supply tank, it is provided with an air pipe carried through the roof. During the time of maximum demand at all the fittings, this pipe becomes empty and the water level in the tank D gradually lowers; the normal pressure in the pipe supplying the second-floor range is also considerably reduced by the excessive draught made upon it. Also, as the 1-in. pipe G is subjected to

the head of water in the cold tank, which is several feet more than that to which it is subjected by the tank D, there will be a tendency for the water to flow through the $1\frac{1}{4}$-in. secondary flow and 1-in. secondary return from the cylinder towards the tank D instead of in the opposite direction. The 1-in. pipe B does not in any way interfere with the efficiency of the secondary circulation.

The **alternative arrangement of branches** to the second-floor lavatory basins is sometimes adopted in the best work, and allows stop cocks to be fixed in such positions that they can be closed without interfering with the circulation. Repairs to these basins can therefore be carried out while the other parts of the apparatus are in use.

It will be advisable at this point to introduce the question of "**Independent Boilers**", although their form, &c., is dealt with in a later chapter. A common idea amongst the public in general, and also to some extent amongst a class of hot-water fitters, seems to be that there is no limit to the heating powers of a "kitchen-fire" boiler, and that the more it is given to do the better it will work. A moment's careful thought will entirely dispose of such a fallacy. The efficiency of a boiler depends upon its heating surface—a fixed quantity—and the size and temperature of the fire with which it is in contact, both of which are limited; therefore the quantity of water which can be heated to a given temperature during a given time is also limited, and any attempt to get more from the boiler than it is able to give will result in failure. Consideration must also be given to the fact that the primary duty of the kitchen fire is cooking food, and not heating the water in the boiler.

It may be argued that the boiler is only receiving surplus heat, which would pass by conduction through the material at the back of the fire if no boiler existed; but this is not quite correct. A solid fire-back soon becomes heated to the same temperature as the fire, and assists combustion, but a boiler presents a more or less cold surface to the fire, as the cooler water in the circulation gravitates to the boiler; the amount of heat abstracted from the fire in this way has, in the case of ranges possessing a number of hot plates and ovens, often proved a disadvantage. The fact that large quantities of hot water are often required during the time that the greatest demand is being made upon the fire for cooking purposes, has often led to difficulty in both branches of household service.

Where large quantities of hot water are required in either large private houses or public institutions, it is always advisable to use independent boilers. Where an ordinary kitchen-range boiler is fixed and found insufficient, an independent boiler may often be arranged for and connected to the existing circulation pipes without making extensive alterations. The kitchen-range boiler may be retained, and will probably serve for the requirements during parts of the day, the independent boiler being brought into action when large quantities of hot water are required. The fire of the independent boiler need not be allowed to die out during the periods when it is not required, but by careful firing may be kept low, and can at any time be brought into full play in a few minutes by opening the damper. Fig. 379 shows an arrangement of this kind, which has been adopted in many such

instances with great success. No addition to the cylinder connections is necessary, so that the work can be carried out without unduly interfering with the supply of hot water.

Under some conditions it will be found necessary to provide more than one hot-water storage tank, owing to the distance which separates groups of fittings. An arrangement is shown in Plate XXII, consisting of **a cylinder and two tanks**, the heating power being provided by an ordinary and an independent boiler. The connections of the pipes from the cylinder to the boilers do not follow the orthodox rule. In the case of the independent boiler, the flow is connected in the usual way to the cylinder about 1 ft. from the top, a by-pass linking it to the secondary flow; the return pipe is taken from the bottom of the cylinder, and to it are connected the two secondary return pipes, which are also connected to the cylinder about midway in the vertical height. This arrangement does not at first recommend itself, it being assumed that water drawn from the branches on the secondary return will partially pass through the $\frac{3}{4}$-in. connection or by-pass from the primary return, and therefore a mixture of hot and cold water will be obtained. This theory is not borne out in actual practice, as the line of least resistance is through the cylinder connection, and also as the water in the upper part of the cylinder is usually much higher in temperature than that in the lower part, and, being lighter, is forced (by the cold water entering the cylinder through the supply pipe) along the secondary return.

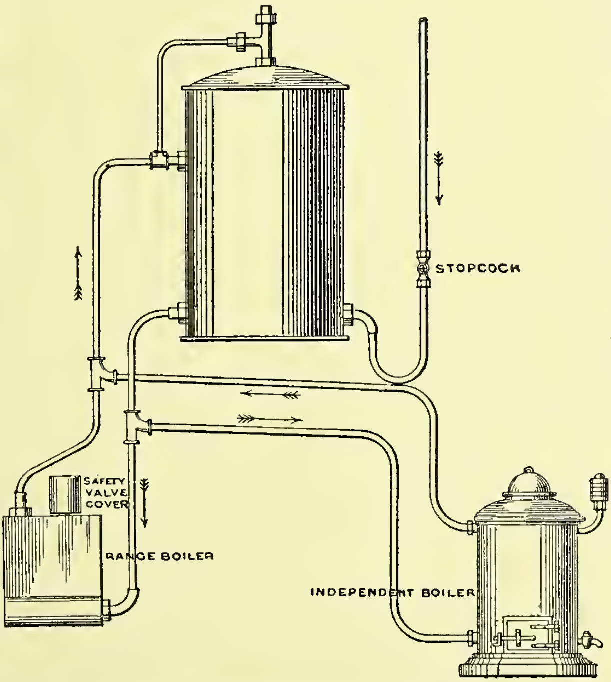


Fig. 379.—Connection of Independent Boiler to existing Circulation Pipes

The advantage of this by-pass is that the water, cooled by its passage through the secondary flow, the storage tank and the secondary return, is delivered mainly direct to the boiler, only a small portion passing into the cylinder.

The $1\frac{1}{4}$-in. flow pipe from the kitchen boiler is taken direct to the top of the cylinder, and connected to the secondary flow pipe at the point where the by-pass of the flow pipe from the independent boiler enters it. The object of such a connection is to facilitate the heating of the water in the

two storage tanks in the early morning. It often happens that large quantities of hot water are required soon after lighting the fires, and as the kitchen fire is usually kindled first, being required for breakfast-cooking, the water heated in the kitchen boiler will pass directly to the two storage tanks, and thereby largely supplement the independent boiler, the fire of

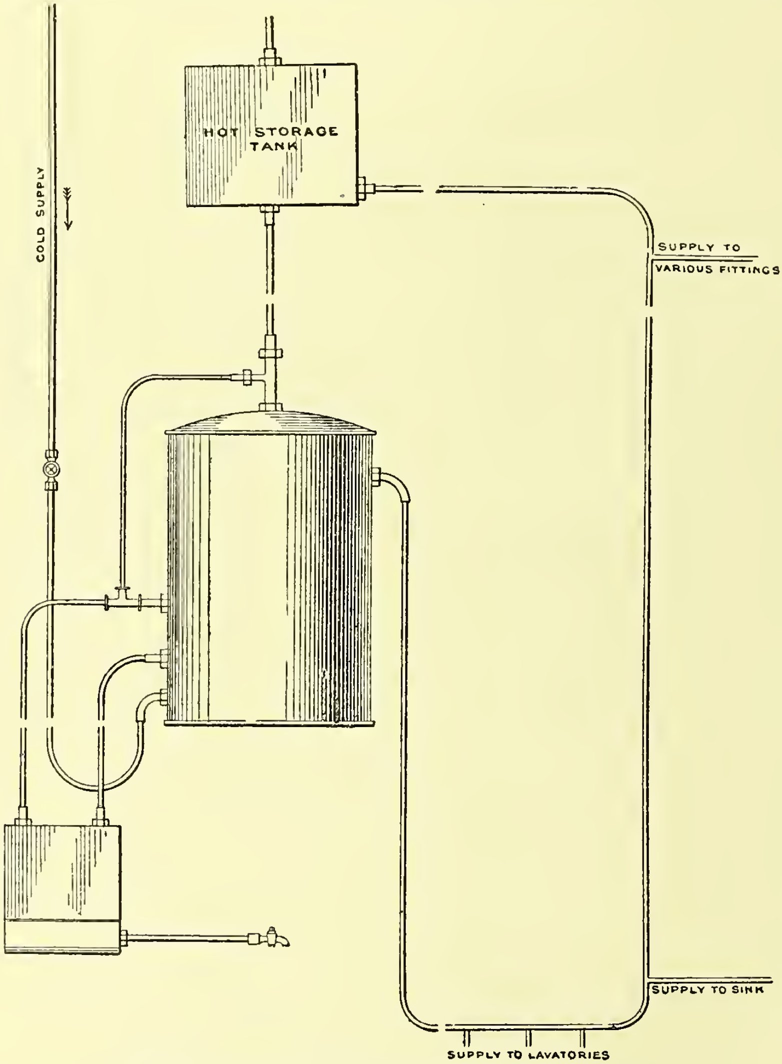
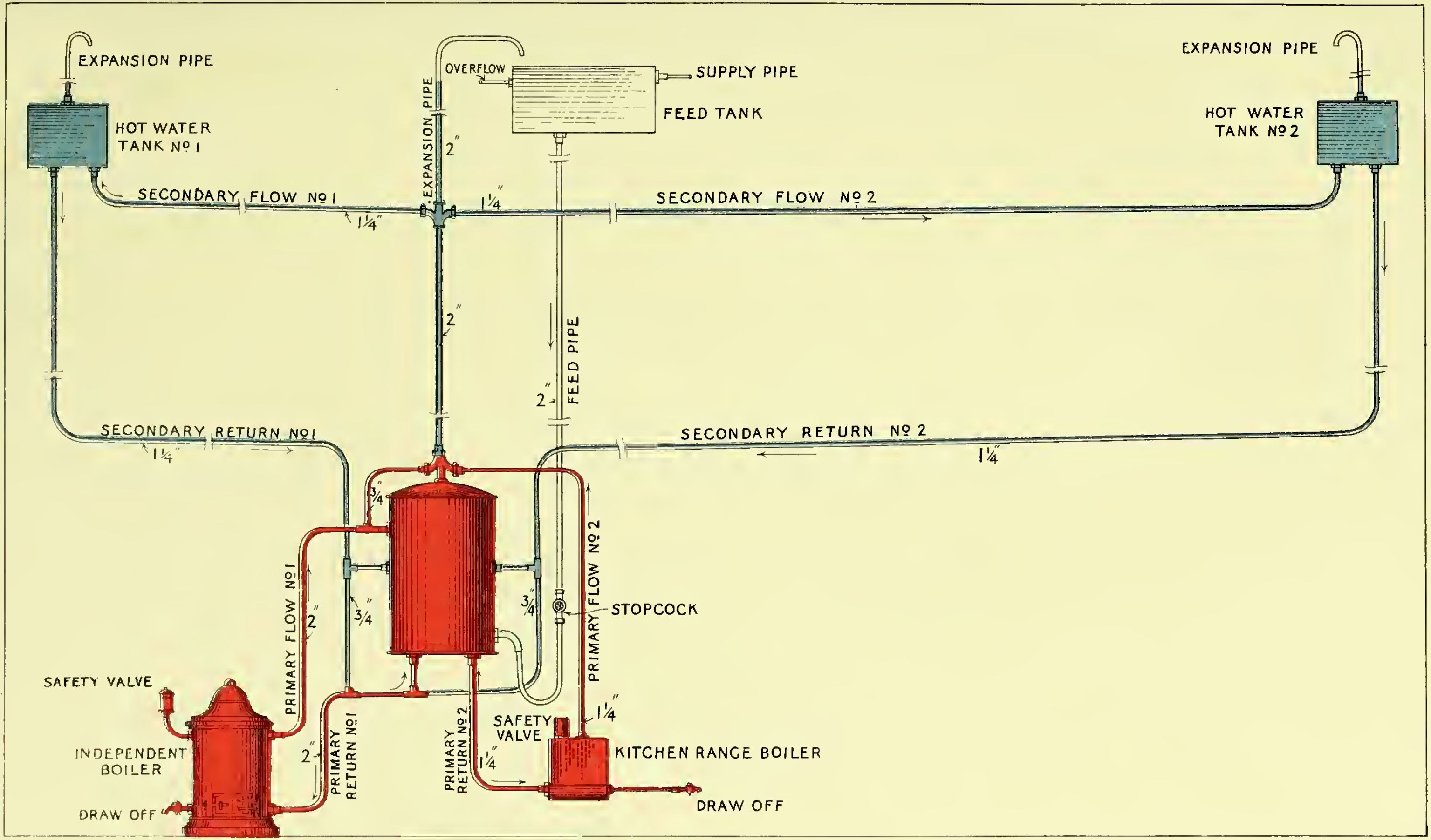


Fig. 380.—Circulation below the Boiler (Cylinder-and-tank System)

which is generally lighted after the kitchen fire. The $1\frac{1}{4}$-in. primary return pipe is connected to the bottom of the cylinder in the usual way.

The 2-in. air pipe constitutes the first part of the secondary circulatory system, and is continued to a point above the top of the cold-supply cistern. Near the top two $1\frac{1}{4}$-in. branches are taken out for the purpose of supplying the two hot storage tanks, and from these two branches the fittings on the



HOT-WATER SERVICES

Cylinder System with Hot Tank and two Boilers

second floor are supplied; those fittings in the immediate vicinity of the tanks are supplied directly from the tanks themselves. The $1\frac{1}{4}$-in. return pipes from both tanks are utilized for supplying the fittings on the first floor, and branches are also taken from them to supply fittings on the ground floor. The supply from the cold-water tank to the cylinder is in 2-in. pipe, and provided with a full-way stop-cock near its connection with the cylinder; bends and horizontal runs should always be avoided in this pipe, to minimize as far as possible the friction on the flow of water through the pipe. Each of the hot-water tanks is provided with an expansion or air pipe taken through the roof well above the level of the water in the cold-supply tank.

Circulation below Boiler.—It is sometimes necessary to supply hot water to a range of lavatories or other fittings in the basement of a building. In many cases the boiler is situated on the ground floor, necessitating a special arrangement if it is desired to secure a good circulation of hot water below the level of the boiler, and avoid drawing cold water when the taps are turned on. Fig. 380 shows an arrangement which works satisfactorily. It is sometimes stated that it is impossible to obtain a circulation of hot water below the level of the boiler, but this is a fallacy. The secondary return pipe in fig. 380 is taken from the side of the hot-supply tank, and after supplying fittings on the uppermost floor it passes vertically down to the basement, where branches are taken off to supply a range of lavatories and a sink. The pipe is then taken up vertically and connected to the cylinder about 1 ft. from the top. If the connection were made near the bottom of the cylinder, lukewarm or cold water would be drawn from the lower part of the cylinder when one of the taps in the basement was opened.

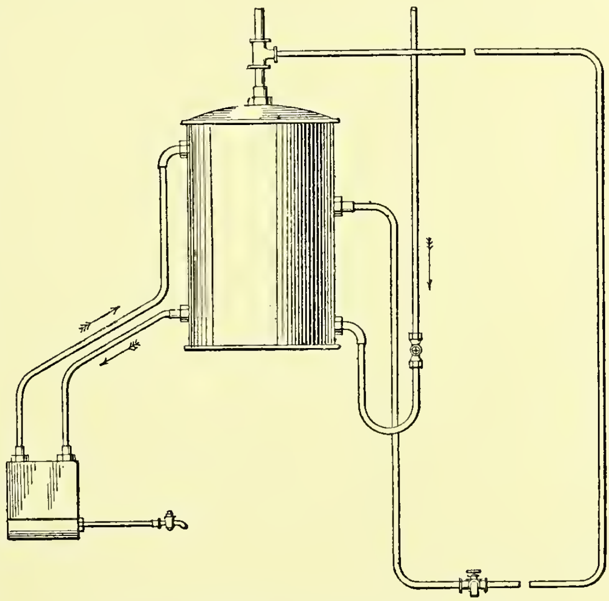


Fig. 381.—Circulation below the Boiler (Cylinder System)

A case was recently brought before the writer's notice where a good circulation was obtained in a similar manner, although no hot storage tank was provided. The branch (fig. 381) was taken from the air pipe about 2 ft. above the top of the cylinder, and after passing vertically downwards from the cylinder to the basement it was taken up and connected to the cylinder a little above the middle of the height.

CHAPTER IV

INDIRECT HEATING AND MISCELLANEOUS SYSTEMS

Deposits in Boilers.—The deposition of the carbonate of lime in temporarily hard waters used in domestic hot-water systems in some parts of the country, causes considerable trouble and expense. During the heating of the water in the boiler, the carbon dioxide is driven off the more rapidly as boiling-point is approached, and the lime is deposited, and gradually accumulates and forms an internal coating in the boiler, pipes, and cylinder. The coating thus formed is very hard, and as the thickness increases, the bore of the pipes is reduced and the flow of the water through them considerably retarded; the accumulation goes on until the pipes are finally almost choked. The inside of the boiler receives the bulk of the deposit, and consequently its heating efficiency is gradually reduced, until the coating becomes so thick, especially on the front and bottom plates, that an adequate supply of hot water is not obtainable. There is also greater wear of the boiler plates, owing to overheating, for the crusted deposit is not a good conductor of heat, and this permits of the boiler plates receiving more heat in a given time than they can impart to the water; consequently those in direct contact with the fire are often red hot.

This condition of affairs, apart from the probability of a boiler explosion (which will be explained fully in a later chapter), is fraught with a certain amount of danger where cast-iron boilers are used. The "fur" or crust of lime, owing to overheating of the boiler plates, may suddenly crack and permit the water to pass quickly through the fissures to the red-hot plate; this will cause rapid contraction in portions of the plates and a greater tension in other parts than the metal can sustain, and a fracture will occur; this allows a discharge of steam and hot water to take place, and, if a large portion of the plate is detached, the system is emptied in a short time and much damage and not a little danger may be incurred.

There is no risk under the same conditions if a wrought-iron or copper boiler is used, as these metals are fibrous and very rarely fracture.

Water-softening Apparatus.—There are various systems in vogue, the object of which is to prevent or minimize deposit. One, which the writer has had the opportunity of carefully studying, consisted of an attempt to precipitate the $CaCO_3$ (calcium carbonate) by what is known as Clarke's process. Several open cylindrical tanks were provided, and into one of these a quantity of quicklime (CaO) was automatically added and mixed during the delivery of water into the tank. The remaining tanks were used for filtering out the portion of the precipitate which passed with the water from the first tank. After passing through the filters, whose medium consisted of mineral charcoal, the water was received into a large tank, the ball tap of which controlled the supply to the first tank. The supply to the hot-water system was taken from the large tank. After the installation had been at work for several months, the boiler and pipes were examined and found thickly coated with lime; this was, however, proved to be due

to faulty adjustment of the quantity of CaO added to the water by the special apparatus provided.[1]

Another method for reducing the quantity of deposit is known as the **Indirect Heating System.** In this arrangement advantage is taken of the fact that the CO_2 is driven off and deposit of lime occurs to a far greater extent when water approaches or is actually at boiling-point, than when the temperature of the water is below 190° F. There are several types of this system, ensuring the prevention of contact between the water heated for use and the boiler plates subjected to the fire heat.

The first example to be considered has **a double boiler,** as shown in fig. 382. The water heated for domestic supply does not come in contact with the heated boiler plates, but obtains its heat by conduction through the plates of the inner boiler, from the water in the outer boiler. The temperature obtainable in the circulation pipes and cylinder rarely exceeds 160° F., and is often not more than 100° F.; therefore the deposit of carbonate of lime is very slight, and the periodical cleaning out of the boiler, pipes, and cylinder is rendered unnecessary. The water employed for heating purposes is used over and over again, the only loss being due to the escape of steam and evaporation. The deposit consequently is an almost negligible quantity, as no water is drawn from this part of the system for use. A separate tank of small capacity is provided, fed by a ball tap, connected to a branch from the supply to the cylinder. A pipe from this tank keeps the outer boiler filled with water, and an air or expansion pipe is fixed to the top of the boiler and turned over the small tank a little distance above it. The arrangements of the flow and return pipes in connection with the inner boiler are similar to those previously described.

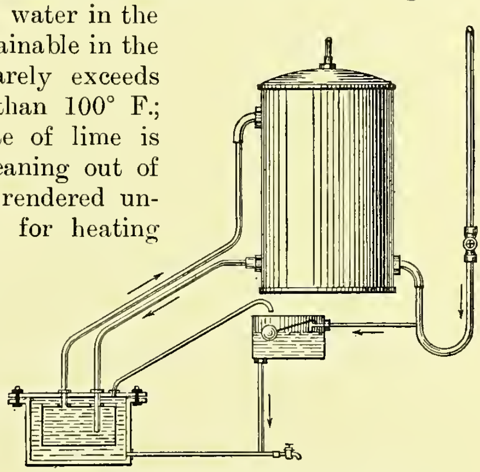


Fig. 382.—Double-boiler System for preventing the deposit of $CaCO_3$ (calcium carbonate)

Where a large quantity of hot water is periodically required, this method of supply is unsatisfactory, as the water in the inner boiler does not receive heat at the same rate as the water in the outer boiler. This is due to the fact that much of the heat conducted from the fire to the outer boiler plates in contact with it is not transmitted to the inner boiler. The greatest heat obtainable in contact with the plates of the inner boiler is the boiling-point temperature of the water in the outer boiler, and the heat from the water in this boiler, passing slowly by conduction through the plates of the inner boiler, gradually raises the temperature of the water in the supply system, but the rate of conductivity is slow.

It is claimed for this system that the risk of boiler explosion is entirely eliminated, and that no perennial expense for cleaning out the boilers, pipes,

[1] For other methods of softening water, see Section V, Chapter XII.

and cylinders is incurred. Both claims are to a large extent true. A safeguard against risk of explosion can, however, be readily obtained by a simple and inexpensive appliance attached to the boiler of an ordinary system, without in any way affecting its efficiency. As regards the latter claim, it would appear undesirable to incur the constant inconvenience of a lukewarm supply, in order to save the occasional trouble and expense attending the removal of deposit from the apparatus.

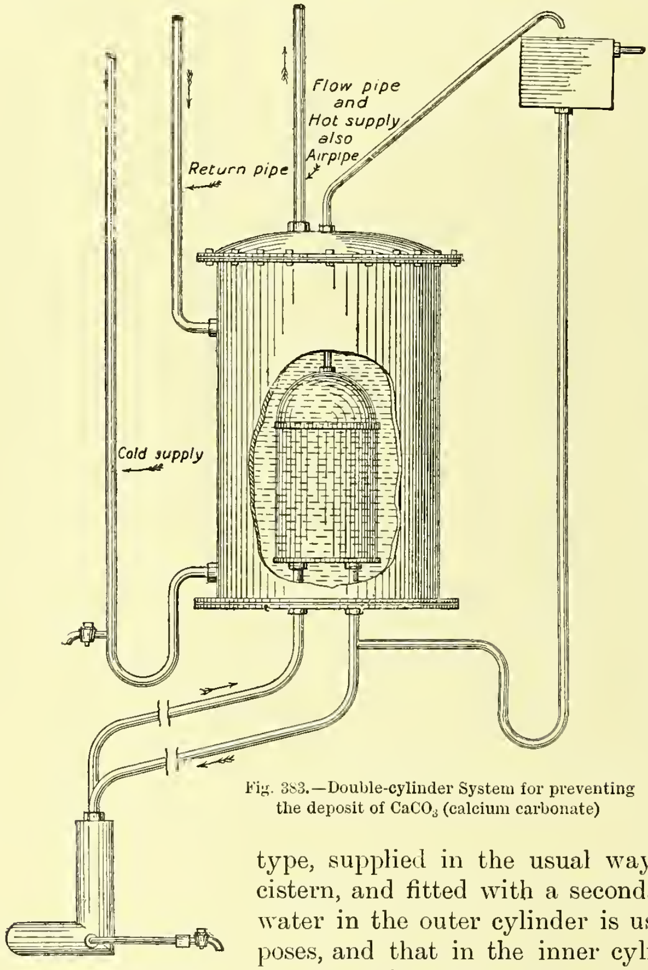


Fig. 383.—Double-cylinder System for preventing the deposit of $CaCO_3$ (calcium carbonate)

A second method is shown in fig. 383, where **a double cylinder** is provided. The inner one communicates directly with the boiler by the usual flow and return pipes, and possesses an air pipe, which passes through the top of the outer cylinder. The supply of water is derived from a special tank, connected by a pipe to the return to the boiler. The outer cylinder is merely one of the ordinary type, supplied in the usual way from a cold-supply cistern, and fitted with a secondary circulation. The water in the outer cylinder is used for domestic purposes, and that in the inner cylinder is used only as a medium for conveying the heat from the boiler to the water required for use. This system cannot be said to give much satisfaction, and is open to the same objection as the previous one, namely, the generally low temperature of the water drawn at the hot-water taps.

A third system (fig. 384) is on the same general principles as the previous one, but has several modifications of detail. The heating surface in the cylinder consists of the superficial areas of the two pipes, which pass diagonally from the top to the bottom of the cylinder (the top ends of the pipes where they project through the cylinder are open), and the dome-shaped false bottom under which the water from the boiler circulates. The total heating surface in this system is therefore less than that available in

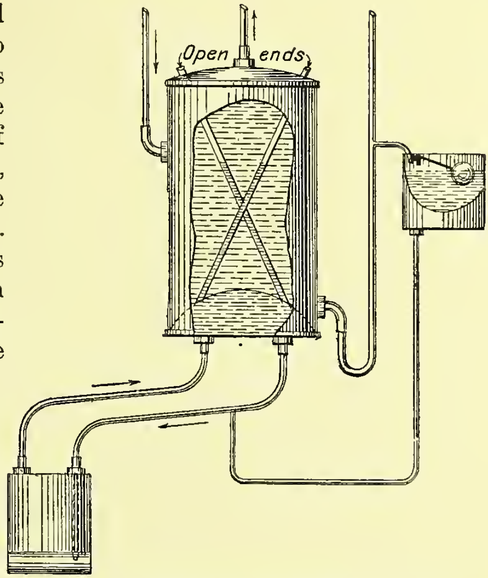


Fig. 384.—Special System for preventing the deposit of $CaCO_3$ (calcium carbonate)

the second method described, and consequently its efficiency is also less. It undoubtedly accomplishes the object for which it exists—the prevention, in a large measure, of the deposit of carbonate of lime, by keeping the temperature of the water used below the boiling-point. The last two systems are just as liable to boiler explosions from certain causes as the ordinary system. A full explanation of these will be given later.

Combined Warming and Hot-water Supply Systems.—In some public institutions, where the warming of the various parts of the building is provided for by low-pressure hot-water heating systems, the hot water required for baths, lavatories, and kitchen purposes is heated by the boiler employed for warming the buildings. This arrangement is never entirely satisfactory under the best possible circumstances. The pipes used for heating purposes are always, under such conditions, made of wrought or cast iron. This is no disadvantage if the water is hard (temporarily), as the water, owing to a deposit upon the interior of the pipes of a thin film of lime, which takes place soon after the system has been in operation, has very little rusting action upon the pipes; but if the water is comparatively pure and well aerated, or slightly acid, a rusting action is started, and in the arrangement shown in fig. 385 rust-laden water may be drawn at the hot-water taps. This arrangement also necessitates the firing of the heating apparatus during summer and winter; but as the boiler is of sufficient heating capacity for warming the whole of the building in the coldest weather, a small amount of fuel in summer will keep the

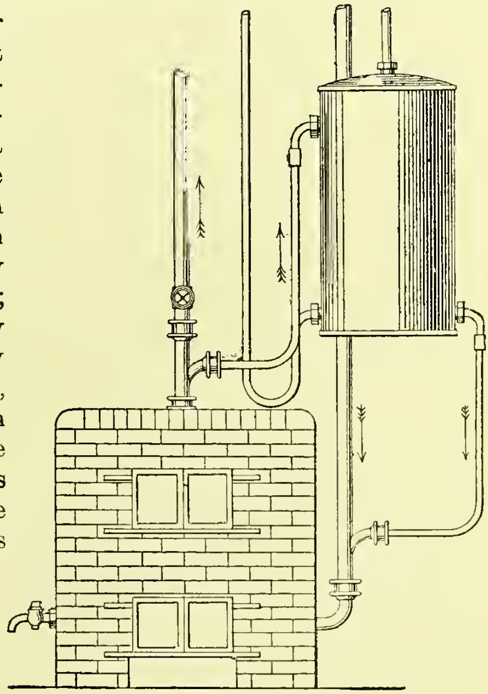


Fig. 385.—Connection of Cylinder to Arrangements in use for Heating the Building

water in the cylinder almost constantly at boiling-point, when the disc valves on the "heating" flow and return pipes are closed. No stop cocks should be fixed on the cylinder circulating pipes, and those on the heating flow and return should be of the disc or baffle pattern, which readily open when the pressure on the boiler side is greater than that on the pipe side of the disc.

Under circumstances just described the water is sometimes heated by inserting a **coil in the cylinder**, as shown in fig. 386, so that there is no contact between the water in the cylinder and that in the heating system; but this method, although it fully obviates the disadvantage mentioned previously, is open to the same objection as exists in the systems illustrated by figs. 382, 383, and 384, namely the slow heating of the water. Where the water supplied to the apparatus is temporarily hard, a direct connection of the cylinder to the heating-apparatus boiler, as in fig. 385, would not be permissible, as some portion of the water in the "heating system" would be continually passing into the "hot-water supply system" and vice versa, and a slight deposit of lime would be constantly taking place, which would in time attain to serious proportions, greatly reducing the conductivity of the pipes and boiler, and exposing the boiler to risk of fracture.

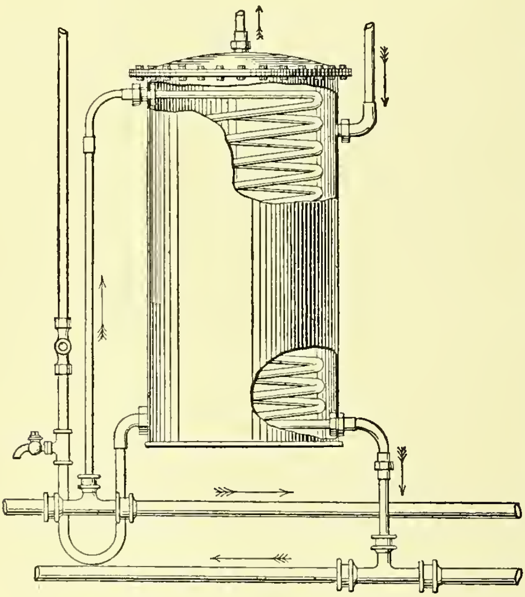


Fig. 386.—Cylinder with Coil

Independent Boiler.—The combination of a hot-water heating system with a hot-water supply system is not, as a rule, economical. Where such an arrangement proves unsatisfactory, the flow and return pipes to the cylinder may be disconnected from the heating pipes and connected to a new independent boiler, and an entirely separate system formed, which will not fail to give satisfaction, and will be more economical than the old arrangement.

To convert an old tank system into a cylinder system without disturbing to any great extent the existing pipe routes and connections, it is best to obtain a cylinder specially suited, as regards the position of the connections, to the requirements of the case. Fig. 387 shows a "conversion" of this kind; the cylinder possesses two connections at the top; A is the secondary flow which rises up to the tank; the return, B, is connected to the top of the cylinder, but is continued by means of a dip pipe to or below the centre of it. The difficulty in this instance is the existing connection of

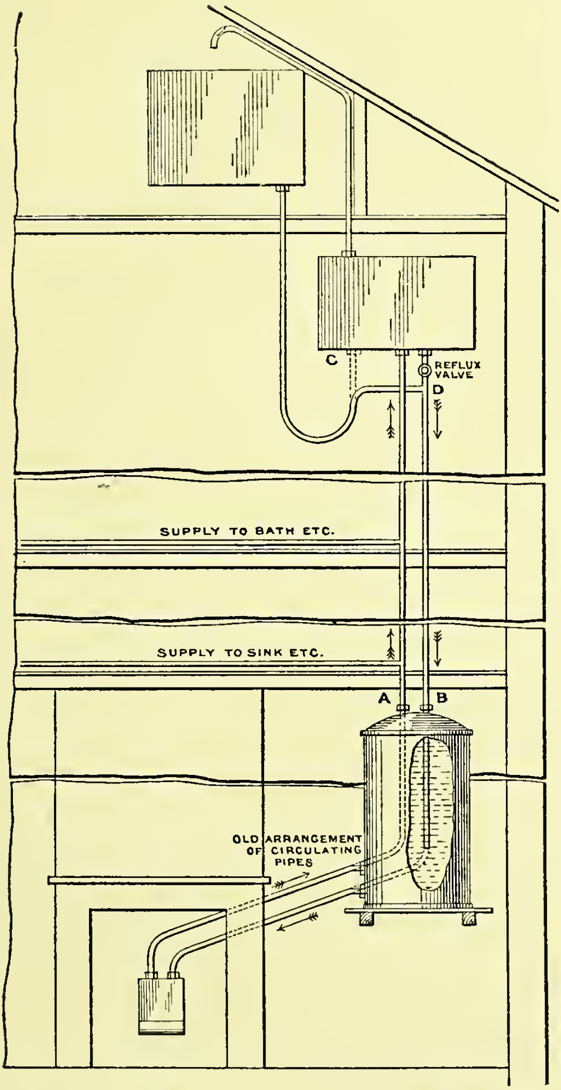


Fig. 387.—Conversion of the Tank to the Cylinder System

the cold-supply pipe to the tank at C; this would prove unsatisfactory, and if the expense attending the continuation of it, with the object of connecting it to the cylinder in the usual way, is out of the question, another method must be resorted to. The connection to the tank at C is abolished, and the supply made to enter the secondary flow about 2 ft. below the tank, and between the connection and the tank a reflux valve (fig. 388) is fixed to prevent a large quantity of cold water from passing directly into the tank, when the greatest demand is being made upon it.

The reflux valve is like an ordinary stop valve minus the spindle and crutch, and permits a flow of water freely in one direction, but a reverse current closes the valve.

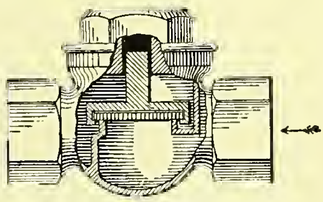


Fig. 388.—Reflux Valve

CHAPTER V

HEATING BY STEAM

Heating water for domestic use by steam is a great advantage where steam is generated on the premises, or in their vicinity, for other purposes, but if no steam is available from any such source it would be most extravagant to generate it specially for heating water.

There are several points to be considered before proceeding to the fixing and arrangement of steam-heated apparatus; and it may be stated that such systems are rarely found even in large private houses, but are more generally confined to public institutions and hotels.

The various points requiring consideration are:—

1. The calorific value of steam.
2. The pressure of the steam and regularity of supply.
3. The quantity of steam available.
4. The quantity of hot water required.

1. **The Calorific Value of Steam.**—It was explained in Chapter I that 1 lb. of steam at 212° F. (boiling-point of water), on being condensed to water at the same temperature, gives out as much heat as will raise the temperature of 966 lb. of water through 1° F. If the steam is under pressure, the temperature is increased, and the greater the pressure the higher the temperature, as shown by the following table of approximate temperatures of steam at given pressures:—

Excess of pressure above normal atmospheric pressure in lb. per sq. in.	Temp. in °F.	Excess of pressure above normal atmospheric pressure in lb. per sq. in.	Temp. in °F.
0	212°	40	286·6°
1	215·9°	45	292·3°
5	227·6°	50	297·5°
10	239°	60	307·2°
15	249·8°	70	315·9°
20	259°	80	323·7°
25	267°	90	331°
30	274°	100	337·8°
35	280·2°		

There is, therefore, a distinct advantage in using steam at high pressures for the work under consideration, and the property which renders it such a valuable heating agent is its "latent heat". The heat required to raise 1 lb. of steam through any number of degrees, (say) from 212° to 312° F., is only ·475 of the amount required to raise an equal weight of water through the same number of degrees, (say) from 32° to 132°; in other words, the "specific heat" of steam may be stated as ·475, and 1 lb. of steam, in cooling any number of degrees to 212° F., will give out sufficient heat to raise the temperature of slightly less than ½ lb. of water the same number of degrees, or will raise the temperature of 1 lb. of water slightly less than half the number of degrees.

Exhaust steam from stationary engines may sometimes with economy be used for heating water for domestic use.

2. **Steam Pressure.**—Steam under a pressure of 1 to 10 lb. per square inch will give the best results. It is not necessary to have the pressure above 10 lb., although where higher pressures are already at hand they may be adopted, if they will not necessitate the strengthening of the apparatus. Where "exhaust steam" is used, an auxiliary supply of "live steam" should be provided, to maintain regularity of heating, and to avoid the necessity of depending entirely upon the engines for a steam supply

when perhaps they may not be working. The connections for such a supply are easily made.

3. **The quantity of steam available** is also an important consideration. If the boiler is not of sufficient capacity for all requirements, then the work for which the boiler was originally intended will suffer, in consequence of the supply to the hot-water apparatus; this point should there-

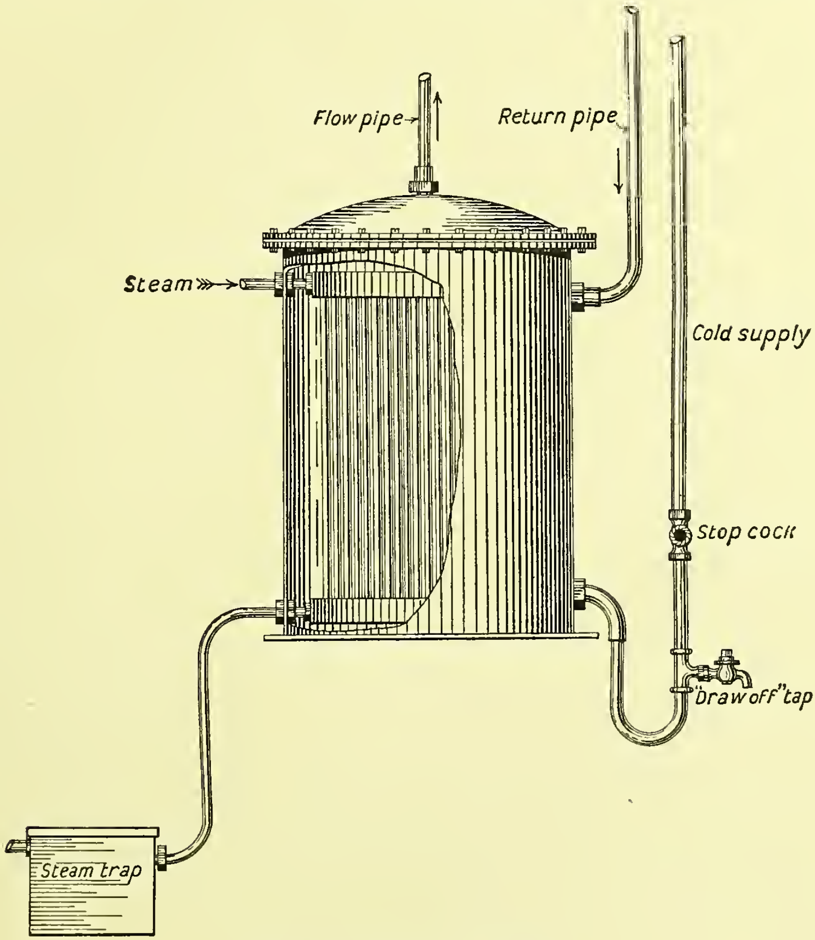


Fig. 389.—Steam Calorifier and Fittings

fore be taken fully into account when adding such extra work to existing steam boilers.

4. **The quantity of hot water required** will of course vary with the size and nature of the building in which the apparatus is fixed, the number of fittings to be supplied, and the particular requirements of the inhabitants of the building.

There are **two principal methods of steam heating**, one of which consists in discharging steam directly into water, and the other in the interposition of a metal which prevents direct contact between the steam and water, and

through which heat is imparted to the water by conduction. The first is seldom followed, except for heating water in open tanks or sinks, or for laboratory and other purposes. It is by far the speediest method of raising the temperature of water, however, as the latent heat of the steam is immediately imparted to the water by its almost instantaneous condensation. This system is not suitable for domestic hot-water supply purposes, but has been adopted for hospitals and factories, and is described on pages 42 and 43.

Steam Heaters or Calorifiers.—The simplest form of steam heater or "calorifier" consists of a cylinder (fig. 389) containing a coil or series of iron or (preferably) copper pipes, in which the steam is condensed, the water in the cylinder being heated by conduction from the coil. The quantity of heated water which can be obtained from the apparatus in a given time will depend mainly upon the area of the condensing surface, *i.e.* the interior surface of the coil in the cylinder. It therefore follows that if this be increased, the quantity of water heated to a given temperature in a given time will be also increased.

The rate at which steam imparts its heat to the water, through the metal of which the coil is made, depends upon (*a*) the difference in temperature of the steam and water, and (*b*) the conductivity and thickness of the metal. The thickness rarely exceeds $\frac{1}{4}$ in., and the following particulars are based upon the results of experiments, where the metal between steam and water was copper $\frac{1}{4}$ in. thick.

It has been demonstrated that 1 sq. ft. of steam-condensing surface will pass or transmit to the water in contact with it 330 British Thermal Units per hour for each degree of difference in temperature between the water and the steam, or 5·5 B.T.U. per minute. Thus, if a 1-in. pipe coil, 42 ft. long, be inserted in a cylinder, the total heating surface will be

$$D\pi L = \frac{1}{12} \times \frac{22}{7} \times \frac{42}{1} = 11 \text{ sq. ft.},$$

where D = diameter in feet, and L = length in feet.

Assuming that the steam enters the coil at 5 lb. pressure, how much water at 50° F. will be heated to 180° F. in 15 minutes?

The temperature of the steam at this pressure will be about 227° F.; therefore, taking the mean of the differences of temperature between 227° and 50°, and 227° and 180°, a mean difference of 112° F. is obtained. Hence 11 sq. ft. of heating surface will transmit

$$\frac{11 \text{ sq. ft.} \times 330 \text{ B.T.U.} \times 112^\circ \times 15 \text{ min.}}{60 \text{ min.}} = 101{,}640 \text{ B.T.U.}$$

in 15 min., and the amount of water which will be heated in that time from 50° to 180° F. will be

$$\frac{101{,}640}{180 - 50} = 781{\cdot}8 \text{ lb., or } \frac{781{\cdot}8}{10} = 78 \text{ gal. approximately.}$$

If it is desired **to ascertain the coil "heating surface"** required to heat

a known quantity of water through a given number of degrees in a stated time, the following formula will be found useful:—

$$S = \frac{L \times R}{H \times M \times T}, \text{ in which}$$

S = interior coil surface for condensing steam,
L = pounds of water requiring to be heated in a given time,
R = required number of degrees of increase in temperature of the water,
H = number of heat units transmitted by 1 sq. ft. of heating surface per minute, = 5·5 B.T.U.,
M = mean difference in temperature of steam and water,
T = time in minutes in which the water is to be heated.

Example.—Required to find the heating surface necessary for raising the temperature of 30 gal. of water in a cylinder from 50° to 180° F. in 30 min., the temperature of steam available being 220° F.

The coil surface (internal) $= \frac{300 \text{ lb.} \times 130°}{5·5 \times 105° \times 30 \text{ min.}} = 2\frac{1}{4}$ sq. ft., and the required length of pipe 1 in. in diameter (*i.e.* $\frac{1}{12}$ ft.) will be

$$\frac{2\frac{1}{4}}{\frac{1}{12}\pi} = \frac{9}{4} \times \frac{12}{1} \times \frac{7}{22} = 8·6 \text{ ft.}$$

The above method is not strictly accurate, especially where there is a wide range of temperature between the water entering the cylinder and that leaving it in a heated condition; for it will be seen by the preceding statements that the greater the difference in temperature between the steam and the water the more rapidly will the latter be heated, and as the water increases in temperature, this difference is correspondingly reduced, and the rate of heating of the water is also reduced. To obtain more accurate results, it is usual to find the mean of from six to ten calculations obtained by the above formula.

For example, in the calculation previously given, where the difference in the temperature of the water entering and leaving the cylinder is required to be 180 − 50 = 130° F., ten separate calculations would be advisable; thus:—

1st, heating surface necessary to raise temperature of water from				50° to 180°	in 30 minutes.
2nd,	"	"	"	63° to 180°	"
3rd,	"	"	"	76° to 180°	"
4th,	"	"	"	89° to 180°	"
5th,	"	"	"	102° to 180°	"
6th,	"	"	"	115° to 180°	"
7th,	"	"	"	128° to 180°	"
8th,	"	"	"	141° to 180°	"
9th,	"	"	"	154° to 180°	"
10th,	"	"	"	167° to 180°	"

The above results added together and divided by 10 would produce a fairly accurate answer.

A simple apparatus embodying the principle just discussed, and one which works admirably, is shown in fig. 389. It consists of a number of copper pipes fixed vertically inside a cylinder, the top end of which is detachable; the steam enters at the top connection, and passes from it into the vertical pipes, where it is condensed by the pipes being in contact with the water in the cylinder. The condensed water passes through the bottom connection, and may be disposed of in several ways. In some instances the steam is allowed to pass directly into the atmosphere, or is discharged into a tank of water, or over a trapped drain connection. In these methods there is nothing to prevent steam from blowing or escaping into the open air, when the water in the cylinder is near the boiling-point and condensation is consequently slow. This is unsatisfactory, as the steam condenses on the walls, &c., in the vicinity, causing damp, as well as being a loss of power, and also of fuel.

Steam Traps.—The best method of obviating this is by the insertion of a suitable steam trap, which, while permitting the water to escape, entirely closes the exit to the passage of steam. These traps may with advantage be fixed near the apparatus, so as to reduce as far as possible the length of pipe between them and the cylinder, and thus minimize the condensation which is constantly going on in the pipe outside the cylinder. There are no great objections or difficulties in connection with the fixing of such traps inside buildings, as they are entirely enclosed, and when in good order no escape of steam occurs.

There are many types of trap, a few of which are very efficient, but only two will be mentioned, briefly. The first consists of an enclosed cast-iron box, fitted with a ball valve of peculiar construction, possessing a hollow arm, down which the water flows into the ball, causing it to sink gradually. This action opens the valve and permits of a quick discharge of the results of condensation into the arm, and through to the ball, forcing the water out and causing it to rise and almost close the valve. This action is continually repeated as condensation takes place.

The second type of trap depends for its efficiency upon the expansion and contraction (due to variation in temperature) of a curved bar of brass, which, when expanded, actuates a spindle and closes the exit valve. The passage of water at a temperature some degrees below boiling-point causes the metal bar to contract, and thus opens the valve. This kind of trap has not proved very reliable in the writer's experience.

Steam heaters or calorifiers connected to cylinders have the same effect as an ordinary boiler. The heater is usually comparatively small in size, but possesses a large amount of condensing surface in the form of a copper coil inside the jacket. Fig. 390 shows an arrangement of this kind. The primary and secondary flow and return pipes are arranged in the same manner as in the ordinary system. The advantage of this type of heater is that it may be applied to an existing cylinder without disturbing it in any way; it would also probably be less costly than installing the coil in the cylinder.

For a large institution, where the sanitary fittings are fixed in a specially constructed adjunct to the main building, known as the sanitary

block, the best method, if steam in sufficient quantities is available for supplying hot water, is to devise a system for supplying the whole of the fittings in the block from a cylinder, if necessary supplemented by a tank for reserve storage. Assuming that the building is three stories high, with six lavatories, one bath, and one sink on each floor, the first consideration will be the size of the tank and cylinder necessary for their supply. It is probable that the greatest demand will take place when the three baths

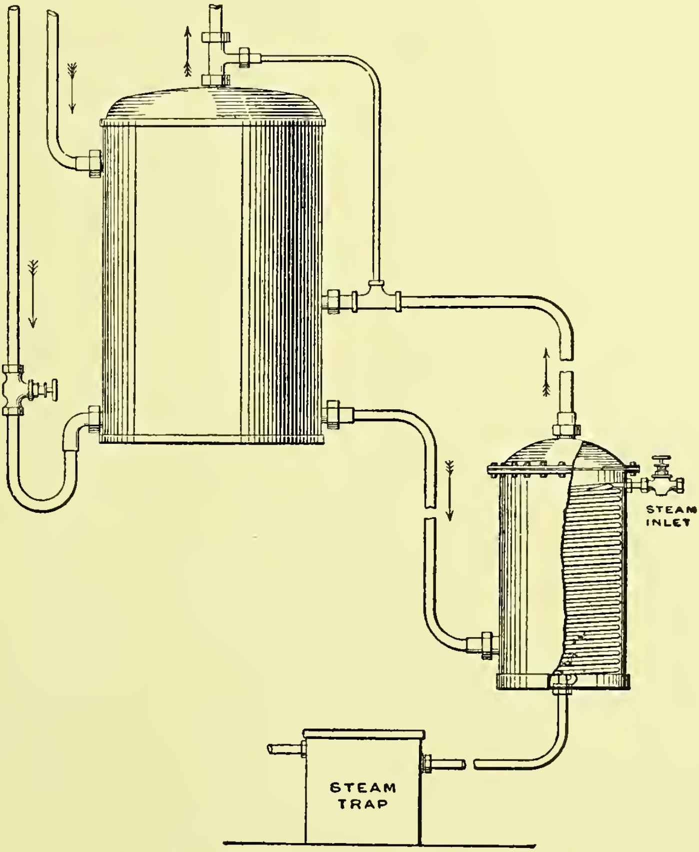


Fig. 390.—Heating Water by Calorifier connected to Cylinder

and (say) one-third of the lavatories are called into use at the same time. 60 gal. of water, at 180° F., in half an hour may be allowed for the lavatories, and 300 gal. in the same time for the baths, making the approximate total 400 gal. of heated water per half-hour. From 60 to 100 gal. of this may be drawn in the first five or six minutes.

Under the circumstances two courses are open for adoption:—

1. The provision for storing from 100 to 120 gal.

2. The provision of a minimum storage, (say) from 50 to 70 gal., with supplementary coils in the cylinder, controlled by separate valves, which may be called into operation during the periods of maximum demand, which occur at stated times each day.

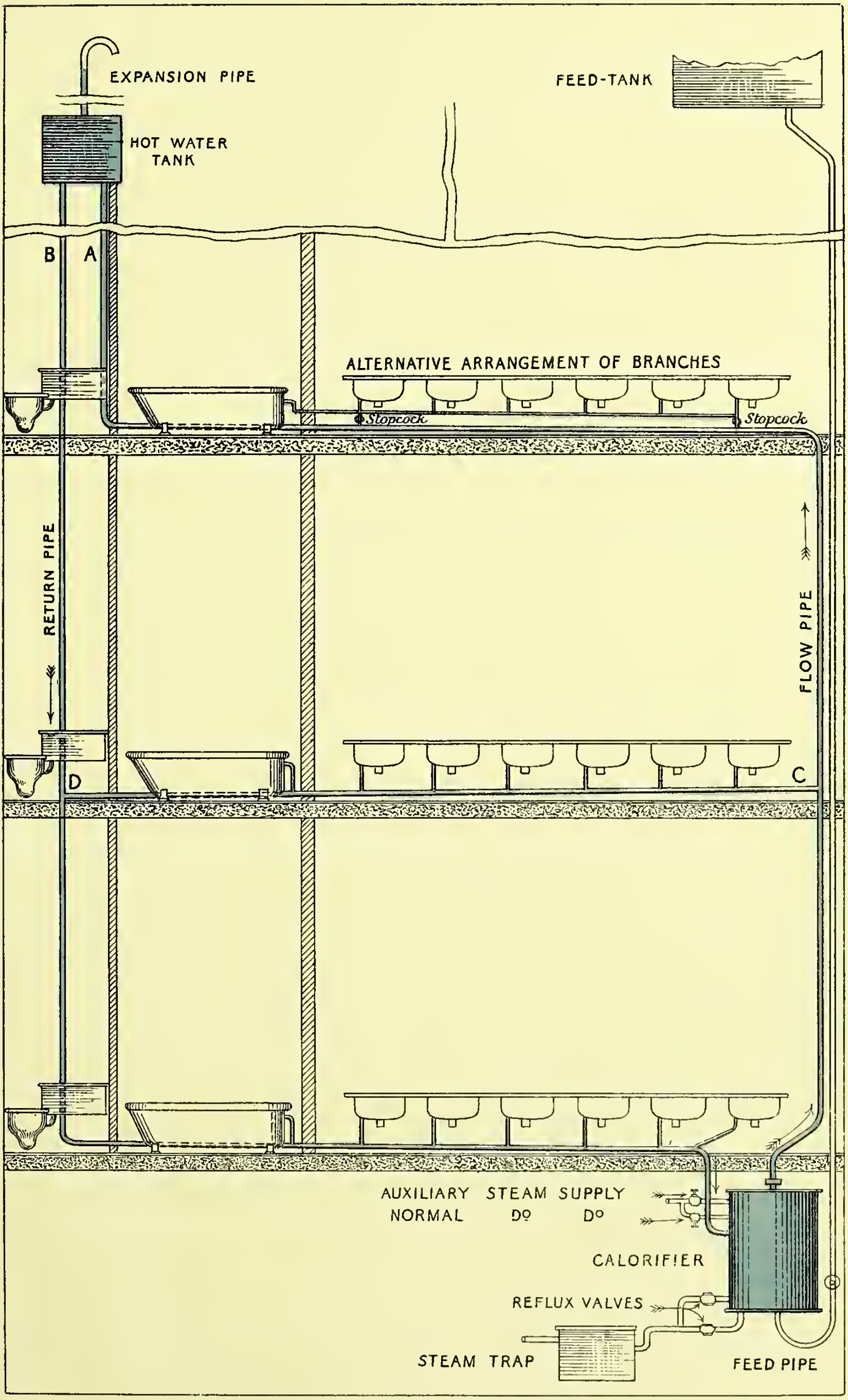
Where there are no attendants, the former system is to be preferred; but the latter requires only a few minutes' attention just before and after the maximum demands of the day, and it is less costly to install, and more economical to maintain. The condensing surface of the coil in the cylinder in the first method is considerably less than that available in the second, where it may be increased three or four times by bringing into play the additional coils.

This arrangement is shown in Plate XXIII. The capacity of the cylinder is 35 gal., and that of the reserve tank 25 gal., making a total of 60 gal. The cylinder contains a normal and an auxiliary coil for use as explained above, and the condensed steam from these is conveyed by a branched pipe to the steam trap. Reflux valves are fixed to prevent steam, either as vapour or in the condensed form, from passing into either of the coils, when one is working and the other is not. The flow and return, A and B, enter the tank at the bottom, and do not project inside, and the through connections at C to D, &c., are similar in principle to the arrangement described on page 25, yielding a maximum quantity of water in a minimum length of time. The diameter of the steam pipe supplying the heater does not require to be greater than $\frac{3}{4}$ in., and in many cases if the pressure is above 10 lb. per square inch a pipe $\frac{1}{2}$ in. diameter will suffice. The arrangement described is under easy control at all times, and if the heating surface of the coils and the capacity of the cylinder and tank are proportioned to meet the requirements, satisfactory results will follow.

Apparatus for Isolated Group of Fittings.—In some public institutions and hotels small groups of fittings occur in such isolated positions that any attempt to supply them with hot water from the general system would be a matter of considerable difficulty and expense; the delivery, owing to the great length of pipe necessary, would be very slow; and the difficulty of avoiding "dead" or cold water being drawn before hot water was obtained would make it imperative that some modified form of separate supply should be provided. Under such circumstances, if a supply of steam is available, a small heater, as shown in fig. 391, may be provided. The cold-supply tank should be fixed at such a height as to give a full supply to all the fittings connected with the apparatus. A steam trap similar to that shown in fig. 390 should be provided, and the expansion pipe may be either turned over into the supply tank, or taken well above it and made to discharge into the open air.

The Instantaneous Water-heater, of which there are many types, heats the water as it emerges from the taps. This system has been adopted in some recently built hospitals, and possesses both advantages and disadvantages. The steam is mixed with the water in a specially constructed chamber when the valves are opened, and the water is thus heated by actual contact with the steam. The cold-water supply and the steam supply are connected to the appliance and provided with valves, which are both actuated at once by a lever or wheel, so arranged that the cold-water valve is opened slightly in advance of the steam valve, thereby guarding against the possibility of the steam issuing at the orifice before it can be condensed.

The advantages of this type of heater are: its low cost, both initially



HOT-WATER SERVICES

Steam Calorifier and Hot Tank

and to maintain, and its capacity for heating water quickly when required, with a minimum loss of heat by radiation. The disadvantages are: that the steam may contain particles of grease in suspension, which will be imparted to the water; and that the valve may be opened when the cold supply is shut off for repairs, causing a sudden discharge of steam, involving risk of scalding.

In one type of heater the steam and water valves are controlled inde-

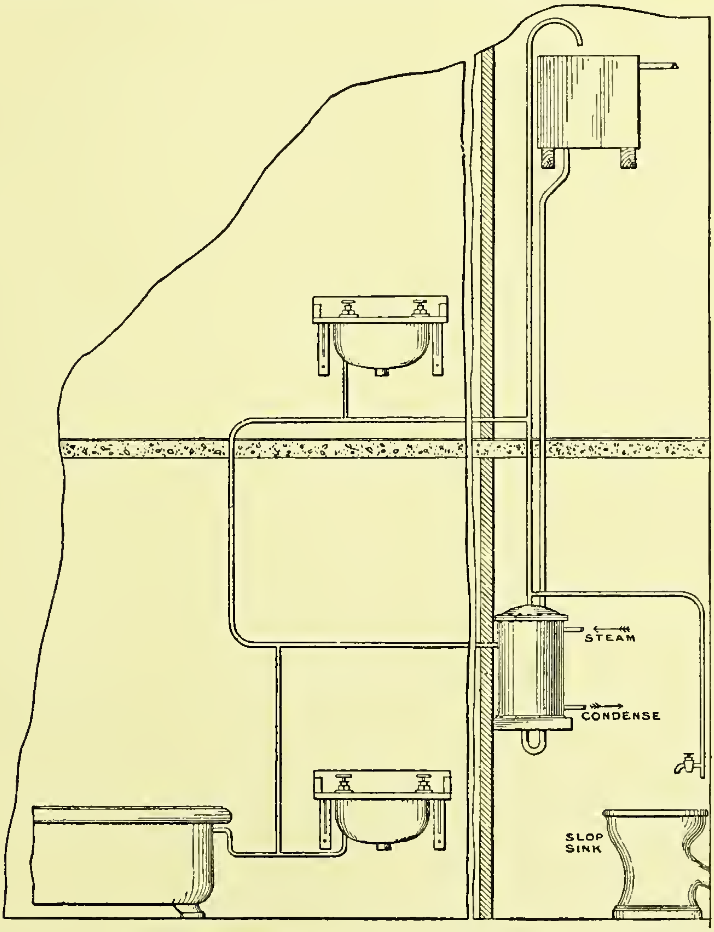


Fig. 391.—Arrangement for Supplying a Group of Isolated Fittings

pendently, and a notice is usually affixed to the valves directing that the cold water should be turned on before opening the steam valve. In another type the outlet is provided with a valve; but this is objectionable, as under some conditions it permits the steam or the water condensed from it to pass into the water-supply pipe, and this may be a source of pollution to the water service. In all types of heater some difficulty is experienced in obtaining an absolutely tight steam valve.

In **mills and workshops**, hot water required for washing, preparation

of meals, &c., may easily be obtained by using a modified form of heater, consisting of a copper casing or cylinder, containing a copper coil connected to the steam supply, the results of condensation being treated as previously described. Fig. 392 shows an apparatus suitable for the purpose. The cold water may be supplied automatically from a small cistern provided with a ball valve, or the supply may be regulated by a stop cock fixed to the heater and connected directly to the cold supply. The supply cistern is generally fixed at the same level as the heater, so that it is not necessary to enclose the cylinder entirely; it may either have a loose top, or be provided with a short tube to permit the steam from the heated water to escape.

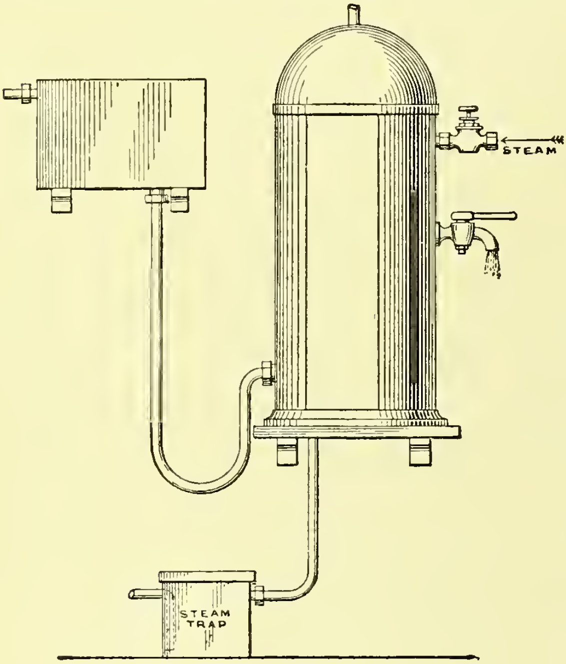


Fig 392.—Arrangement for Supplying Water for Meals, &c., in Factories

CHAPTER VI

RANGE AND INDEPENDENT BOILERS

Range Boilers.—The boiler is the most important part of an ordinary system of hot-water supply. In the writer's experience, numbers of systems giving very unsatisfactory results have been proved, after being condemned and the faults ascribed to other causes, to owe their failure to defective judgment in the choice of boilers.

Materials.—The choice of material of which the boiler is made will be influenced principally by the nature of the water which the boiler is to contain. The metals in general use are copper, wrought iron, and cast iron. Wrought and cast iron do not differ greatly in their rate of conductivity, but are inferior to copper in this respect. A metal with a high rate of conductivity transfers a greater quantity of heat in a given time through its substance than a metal with a lower rate of conductivity, thus influencing the rate at which water is heated.

Cast iron is not a suitable metal for resisting tensile stresses. Owing to its crystalline nature it is readily broken or shattered, and this feature

increases the dangers and risks of kitchen-boiler explosions, the pieces of metal being hurled in every direction. This risk is considerably reduced by the use of wrought iron or copper, because the fibrous nature of these metals permits of elongation taking place under great stresses, with a final parting of the metal showing a stringy fracture; it very rarely occurs that a piece of the metal is separated from the boiler. The greatest risk in such cases would be due to the sudden discharge of large volumes of steam and heated water confined under great pressure.

The thickness of the boiler should not be less than $\frac{1}{4}$ in.; a greater thickness than this is seldom required.

Pure and soft waters attack iron, forming a red oxide, which intimately mingles with and discolours the water. Cast-iron boilers are used very largely in cottages, on account of their cheapness, but where the water is soft they prove very unsatisfactory. The rusting action often forms nodules of oxide in various parts of the boiler, besides unevenly coating it with a scale of oxide, which is a bad conductor and retards the heating of the water. The nodules of rust sometimes gradually form over the flow and return connections, and cause rattling noises by preventing a free flow of water and by causing steam to be generated, which forces its way through the restricted openings and creates a disturbance in the flow pipe during its escape and ultimate condensation. Wrought-iron boilers do not become coated with scale to any appreciable extent, but they are more rapidly acted upon by soft or aerated pure water than those of cast iron.

Various attempts have been made to overcome the rusting action in boilers intended for domestic hot-water supply, but no entirely satisfactory method has yet been discovered. The "Bower-Barff" process, by which iron receives a coating of magnetic or black oxide of iron, has been tried; but owing to the difficulty of entirely coating the interior of the boiler, and the cost, it has not been generally adopted. In this process the protective coating is formed by subjecting the iron to the action of either superheated steam or carbon dioxide heated to a high temperature. The result is the same in both cases: a thin film of black oxide of iron is formed on the surface of the metal, which effectually resists the corrosive action of water if the coating is complete; but if not, the parts of the iron, no matter how small they may be, which remain uncoated are readily acted upon. There is no practicable method known for applying a rust-preventing coating to the interior of iron boilers.

For soft waters there is no more satisfactory metal than copper; the only action which appears to take place is that of the formation of an insoluble substance on the interior surface, which prevents further action taking place. The initial cost is much greater than that of iron; but when a renewal is necessary, the copper of the old boiler is a substantial set-off against the price of a new boiler, while old iron boilers are practically worthless.

Where **temporarily hard water** is used, cast- or wrought-iron boilers are generally adopted, the advantage claimed for them being the comparative ease with which scale may be removed by hammering and chiselling without seriously damaging the boiler. This kind of water has practically

no action upon iron, owing to the early formation of a film of calcium carbonate, which adheres to the metal and prevents corrosion. The writer has seen copper boilers used under such circumstances without any apparent disadvantage compared with iron, the scale being quite as easily removed without any damage resulting to the boiler.

Box or Block Boiler.—There are numerous shapes of boilers in the market, each possessing some special feature. The simplest and most common type is shown in fig. 393. The sloping side is fixed in contact with the fire, and is really the surface upon which the heating efficiency of the boiler largely depends, although this efficiency may be considerably augmented by a suitable arrangement of the brick flues. The whole of the back of the boiler should be exposed to the action of the heated gases which pass under the bottom and up at the back. The back flue should be narrow, not exceeding 3 in. in width from back to front, so that the heat may come in contact with the boiler plate. Fig. 394 shows the flue with a back plate of cast iron, possessing gills which direct the flames and heated gases against the back of the boiler, thereby imparting to it a far greater amount of heat than it would receive if the gases were allowed to pass straight up the flue. At the base of the flue a damper or ash slide of an inexpensive type is fixed, which permits of easy access to the flue daily for clearing purposes.

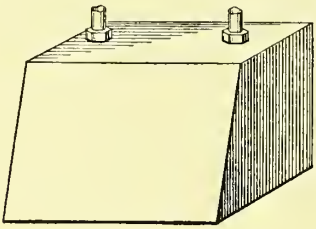


Fig. 393.—Block Boiler

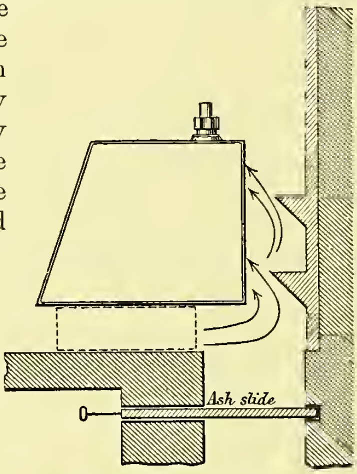


Fig. 394.—Block Boiler with Cast-iron Back Plate and Ash Tray

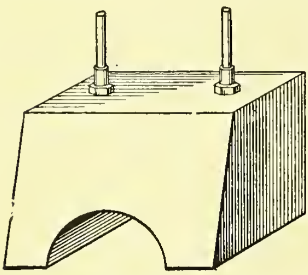


Fig. 395.—Block Boiler with Arched Flue

Boiler with Arched Flue.—A modification of this type is shown in fig. 395, the bottom plate of the boiler being arched. This has the effect of increasing the heating surface, and consequently the efficiency.

These two types of boilers are used largely in the north of England, and are chiefly made in copper and cast iron, though the use of the latter is to be deprecated for reasons already explained. Where the simple cylinder system is installed without any secondary circulation, and the kitchen possesses an open cooking range, these boilers give good results. The arched flue of the boiler in fig. 395 is sometimes modified, and a

rectangular flue substituted, which further increases the heating surface. For a 35-gal. cylinder a boiler with a front 1 ft. square and a square recessed or arched flue will prove satisfactory. It must always be borne in mind that the heating efficiency of the flue surface of a boiler is only on an average one-third that of the surface in direct contact with the fire.

Where the kitchen range is entirely enclosed, **boot boilers** (fig. 396) give great satisfaction. They hold considerably less water than the square or box boilers, for an equal heating surface, and therefore the water they contain is more rapidly heated and forced by the colder water through the circulation pipes. The whole of the boiler, except the top and the two narrow strips at the bottom supporting the boiler, is exposed either to the direct action of the fire or to the flames and hot gases. A clearing damper should be provided at the bottom of the back flue to permit of ashes and soot being easily removed. This type of boiler, when properly fixed and regularly attended to, gives highly satisfactory results in small cylinder systems possessing a secondary circulation.

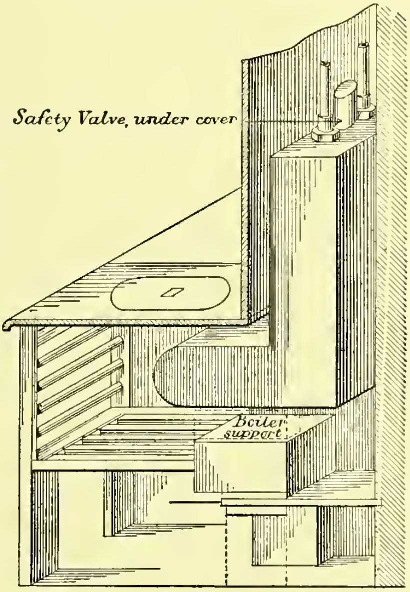


Fig. 396.—Boot Boiler in Position

Arched-flue Boot Boiler.—If an increased heating surface is desired, the bottom or the bottom and back of the boiler may be arched, or constructed with a rectangular recessed flue, which practically doubles the heating surface of those two plates, and consequently adds greatly to the efficiency of the boiler. This arrangement of the plates, shown in fig. 397, proves of great assistance to a system on the cylinder-and-tank principle, the ordinary boot boiler

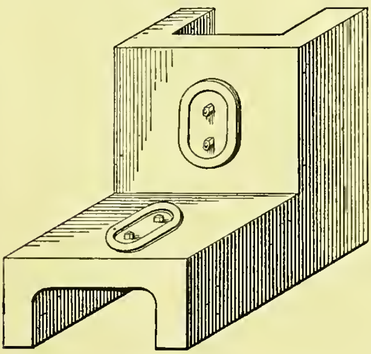


Fig. 397.—Arched-flue Boot Boiler

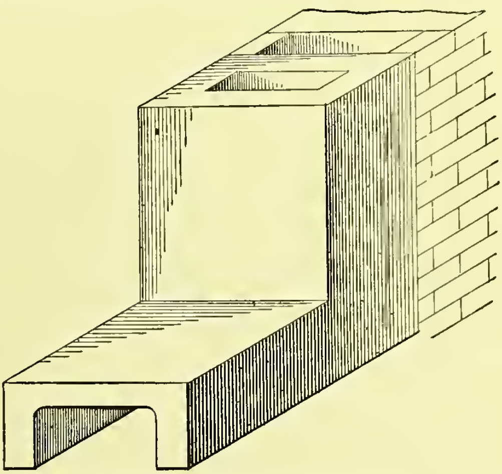


Fig. 398.—Arched Boot Boiler with Enclosed Vertical Flue

being rarely of sufficient heating capacity to satisfy the maximum requirements of such a system.

Boilers with Central Flues.—Fig. 398 shows a further modification of the boot boiler. The heat in this case, instead of passing entirely up the back of the boiler, is made to pass partly up the back and partly through a flue up the centre of the boiler. This modification increases the heating power of the boiler, and renders it suitable for small cylinder-and-tank systems where the demand for hot water is not very excessive.

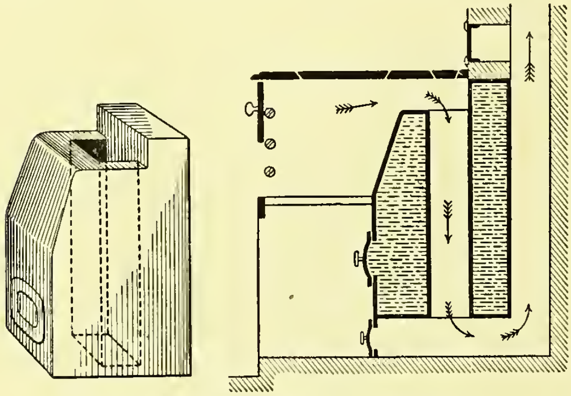


Fig. 399.—Mermaid Boiler with Central Flue

The Mermaid boiler (fig. 399) is of similar type, but all the products of combustion (except when the ovens are being heated) pass down the central flue of the boiler and then up the back. This boiler is particularly useful for hard water, as the deposit takes place almost entirely at the bottom of the boiler, which is below the fire. The upper part continues to transmit heat freely, and the plates are not likely to be burnt out. Access lids are provided for removing the deposit.

A recessed boiler which is adapted for some types of ranges, and which possesses a greater amount of heating surface, is shown in fig. 400. The two projecting sides form the cheeks of the fire box, and the heat passing to the ovens has full play all around them. A flue is provided under and through the boiler, and the back is also exposed to the heated gases and flames. This is an expensive but also very efficient type of boiler, and is specially applicable where large quantities of hot water are required in a small cylinder-and-tank installation.

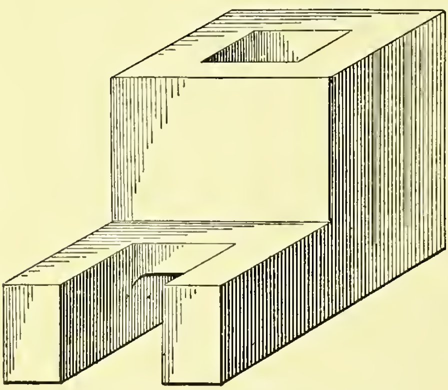


Fig. 400.—Special Form of Boiler with Large Heating Surface

The form of boiler known as Potterton's **Zigzag boiler** (fig. 401) has been used to some extent recently. It consists of two parts, having projections and recesses which fit into each other alternately, forming a flue between the two portions. The zigzag projections greatly increase the heating surface, and therefore the heating capacity, of the boiler. An

additional flue is sometimes provided at the front of the boiler. The two portions are joined together at the top and bottom by means of two 2-in. pipes. In districts supplied with hard water, hand holes are required at convenient points for the removal of scale. Where the quantity of hot water required is such that any of the previously described boilers, except the last, would be inadequate, it would be better to install an independent boiler. If one of the type shown in fig. 401 were used, it would extract a considerable amount of heat from the fire, and would probably interfere with the efficacy of the range for cooking purposes. This form of boiler is also very expensive and difficult to clean.

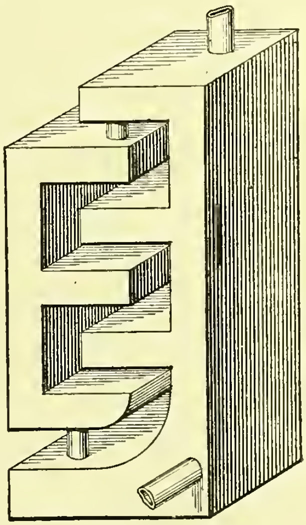


Fig. 401.—View of Zigzag Boiler

Pipe Boilers—Another type of boiler which has been adopted in many cases with considerable success consists of an arrangement of pipes behind the fire box of the range. These boilers are generally made up by the workman who is fixing the installation, or they may be bought ready for fixing. The simplest kind consists of a piece of wrought-iron tube looped in the manner shown in fig. 402.

At first sight it may seem that such an arrangement will be totally inadequate for the requirements of even a small cottage installation, but the heating power of a boiler depends principally upon the direct surface exposed to the action of the fire. Assuming that the fire back is 10 in. × 10 in., the area will be 100 sq. in.; and this represents the total surface of an ordinary box boiler in direct contact with the fire. If a pipe boiler, as illustrated in fig. 402, is substituted, the length of which is (say) 50 in., and the internal diameter 1 in., then the total heating surface will be $50 \times \pi D = \frac{50}{1} \times \frac{22}{7} \times \frac{1}{1} = 157$ sq. in. It will thus be seen that the direct heating surface is considerably greater in the case of the pipe boiler than in that of the box boiler; although, of course, in the latter this is supplemented by the flue surface, which has a heating value of about one-third that of the "direct contact" surface.

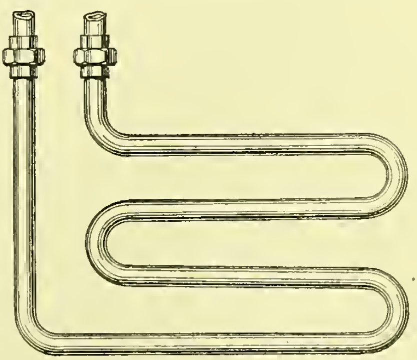


Fig. 402.—View of Pipe Boiler

In fixing this form of pipe boiler, arrangements are made for the fire to have full play all around the tubes, and in order to ensure this the pipe is fixed about $1\frac{1}{2}$ or 2 in. clear of the fire back. Provision is also made for readily disconnecting and removing it without disturbing to any great extent the bricks composing the fire back.

The water in systems provided with pipe boilers is heated more rapidly than in those having the ordinary type. This is due to the fact that the pipe in contact with the fire holds only a small quantity of water, which, being surrounded by heating surface, is rapidly raised in temperature, and forced quickly along the circulation pipes by the colder and heavier water.

Sometimes the boiler is continued from the back to each of the sides of the fire box, and when properly arranged this form proves highly efficient. The area exposed to the fire may be increased or decreased, to suit the requirements of the situation, by altering the diameter or, better still, the length of the pipe when the boiler is installed. In districts supplied with hard water, provision must be made for removing the deposit of lime which will occur.

Fig. 403 shows a pipe boiler which may be made to fit the fire box of an open or closed range. It consists of $1\frac{1}{4}$ in. diameter wrought-iron or copper pipe bent to fit the back and oven sides of the fire box. If wrought-iron pipe is used, the ends are caulked into the sockets in the two cast-iron uprights with gasket and rust cement; if copper pipe is used, the ends are brazed into the return pieces. A tee may be provided in the top pipe for connecting to the flow pipe, and another in the bottom pipe at the opposite side for the return-pipe connection, or the connections may be made to the box ends, as shown. This form of boiler has a large heating surface, and in several instances in the writer's experience has proved very efficient. Some of the heat, however, on its way to the ovens, is absorbed by the side portions of the pipe boiler.

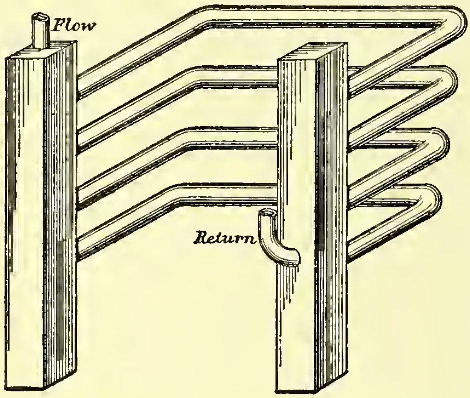


Fig. 403.—View of Pipe Boiler with Box Ends

This boiler may be so arranged that its removal is effected by simply taking off the top plate of the range and disconnecting the unions at the points where the circulation pipes join the boiler, without disturbing any of the brickwork.

Draw-off Taps.—For soft water a copper boiler is necessary, and with the exception of a small pipe connection at the bottom for clearing the sludge from the boiler, no provision for access to any part of it is required. It may be advisable at this point to mention the double advantage of having such a draw-off. The writer has often been asked how it would be possible for a householder who knows little, if anything, about hot-water systems to ascertain whether his boiler and circulation pipes are blocked with ice, or whether it is safe to light a fire after the house has been closed during a period of frosty weather. Apart from the fact that the draw-off pipe acts as a sludge conduit, and is useful for emptying the system for repairs, &c., it provides a satisfactory answer to the above question; for

by turning on the cock provided at the end of the pipe it may easily be ascertained if the system is workably free of ice. If both circulation pipes are blocked with ice, very little water will run from the cock, and the flow will immediately cease owing to there being no air admitted at any point; on the other hand, the water will flow freely from the cock if the system is ice-free.

Access Lids.—Boilers intended for systems supplied with temporarily hard water should always be provided with means of access for the purpose of removing the scale which gradually accumulates as a result of the precipitation of the carbonate of lime. This scale varies in hardness with different waters. If the water contains such substances as clay or sand in suspension, in a very finely divided state, the scale is of a friable nature and not difficult to remove; but some kinds of water deposit a scale so hard that it may be polished, and the removal of this from boilers is a matter of great difficulty. Under such circumstances it is essential that the access openings, or "man-lids" as they are called, should be sufficiently large to allow freedom for the hand and forearm of the workman in working the chisel for the removal of the deposit. Some makers ignore this important consideration, and make boilers with access holes so small that it is impossible for anyone to get more than two or three fingers through the aperture, and the total removal of scale is absolutely impossible. Boilers possessing a number of inaccessible pockets or recesses are not suitable for temporarily hard waters; but a boiler similar in shape to that shown in fig. 397 may be rendered accessible in every part by inserting two man-lids as shown—one in the leg, and the other in the toe of the boiler. All kinds of boot boilers should possess two access lids, as the adequate clearing of the scale from all parts of the boiler is almost impossible where only one lid exists.

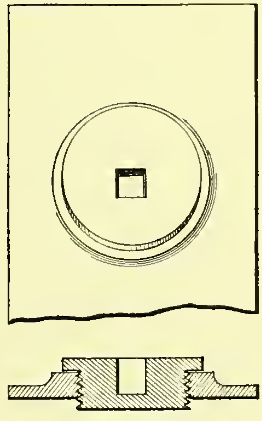


Fig. 404.—View and Section of Screwed Access Lid to Boiler

Various methods are adopted for making the man-lids "tight" to the boiler. One type of circular man-lid occasionally used consists of a disc possessing a thread which screws into a bush specially tapped to receive it (fig. 404). The disc contains a square recess, into which a short piece of square iron bar of suitable size is inserted when it is necessary to remove the lid. This type should not be used, as it is almost impossible to remove the disc with the boiler in position, and to get a water-tight packing is a matter of great difficulty. Boilers having such access lids have frequently to be taken out of the range to enable the lid to be removed, thus entailing extra expense and inconvenience.

The oval man-lid (fig. 405) is undoubtedly the best, as it permits of a greater range for striking with the chisel, and is also not difficult to replace and make water-tight. The method shown in fig. 405 is sometimes adopted for securing the lid to the boiler. It consists of a bridge which fits inside

the boiler, and holds a bolt which passes through the lid and is fixed by a nut on the outside. By tightening the nut the lid is forced against the boiler. The difficulty is to make the fitting water-tight where the bolt passes through the lid; this difficulty, however, may be overcome by reversing the position of the disc and bridge, so that the disc is inside the boiler. The pressure of the water then tends to force the disc more tightly against the seating, and as the bolt in this case is part of the lid, there is no possibility of a leak around the bolt.

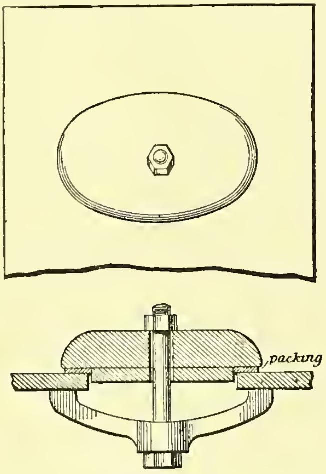


Fig. 405.—View and Section of Oval Access Lid to Boiler

An effective type of access lid which projects very little above the boiler is shown in fig. 406. The discs are in duplicate, one inside and one outside the boiler, and the bolts are shrunk on the bottom disc, obviating the necessity of making a joint. This is probably the most convenient and reliable type of man-lid for kitchen boilers.

Packings.— Various substances are used for making the man-lids water-tight. Hemp soaked in thin red-lead putty, mixed to the consistency of cream, is fairly satisfactory. Brown cardboard is sometimes used, each surface being coated with a layer of stiff red-lead putty before inserting it between the man-lid and the boiler; this also has its merits. Another substance which has been largely used in recent years is asbestos; but although a satisfactory packing for steam-joints, &c., it is not so well suited for positions where it is in constant contact with water, and in the writer's experience its use for such purposes has caused considerable trouble and annoyance, resulting in its being finally replaced by india-rubber. Given moderately even and smooth faces on the boiler and the man-lid, india-rubber is by far the most suitable packing.

Removal of Deposits.—Boilers supplied with temporarily hard water should be attended to at least once every twelve months, but the amount of attention they require should be determined in each case by the amount and nature of the deposit formed in a given time; in a few cases quarterly attention is necessary. It is essential, if the heating efficiency and life of the boiler are to be maintained, that the scale be thoroughly removed periodically, as the deposit reduces the heating power of the boiler, and also permits overheating of the plates to take place with the risk of fracture in the case of cast-iron boilers.

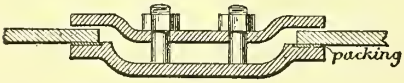


Fig. 406.—Section of Access Lid to Boiler

Boiler Connections.—The connections between the boiler and the two circulation pipes are, in the case of cast-iron boilers, probably the weakest points in the system. The boiler plate is drilled and tapped, and brass boiler unions are screwed into the plate, the thickness of which rarely exceeds $\frac{1}{4}$ in. The length of the screwed portion which enters the boiler

is seldom much less than 1 in., so that the union projects into the boiler to the extent of about $\frac{3}{4}$ in. (No. 1, fig. 407). This permits of an accumulation of air in the boiler, which tries to escape along the flow pipe, owing to its expanding when heated, and causes unpleasant noises. This air is continually added to by air and other gases which are driven out of the water, so that the space shown in No. 1, fig. 407, in the top part of the boiler, is constantly air-locked. To prevent this, bosses ought to be cast on the boiler where the connections are to be made, as shown at B, and the connections are then made with unions to the copper, lead, or wrought-iron circulation pipes. Sometimes when the last-named material is used the connection is made by a long thread and back nut, but this is not a commendable method.

The unions should be made of gun metal and of special strength, and care should be taken to protect them from the direct action of the fire and the gases arising from combustion, by surrounding them with fire-clay. The joint between the two parts of the union should not require any packing, but the parts should be ground together in the lathe during their manufacture, thus ensuring the easy making of a water-tight joint when coupling the circulation pipes to the boiler. Much expense and annoyance are needlessly entailed by the disregard of this detail and the substitution of hempen packing, which, owing to the expansion and contraction of the metal of which the union is composed, and the deleterious effect which heat and water have upon the packing, frequently fails to remain water-tight, and necessitates the removal of brickwork, &c., to make good the defect.

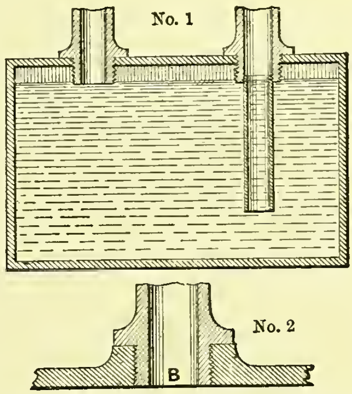


Fig. 407.—Two Sections showing the Wrong and Right Methods of Connecting Pipes to a Boiler

The unions on copper boilers are generally screwed into bosses, which are brazed on to the boiler, and in the case of wrought-iron boilers, bosses of similar shape are riveted in position, and the connections made to them.

When the boilers are being fixed care should be taken to see that they are level, or that the end from which the flow is taken is the higher. The bed upon which the boiler rests should be firm and unyielding.

The positions of the boiler connections are usually decided upon, unless specially ordered, by the makers, and important considerations are often overlooked. Under all circumstances the flow-pipe connection should be taken from the top of the boiler, to prevent an accumulation of air taking place, as is the case when such a connection is made at the side of the boiler. The return pipe is sometimes connected to the top, and a dip pipe taken from it inside the boiler, terminating about 2 or 3 inches from the bottom, or it may be connected to the side of the boiler, near the bottom. With either of these arrangements it is possible for some of the colder water from the return pipe to pass immediately up the flow pipe, thus

reducing the temperature of the hot water which has been in contact with the front of the boiler. This particularly obtains in the case of boot boilers. The best method of connection for the return pipe is to take it in at one of the sides of the boiler, near the front and about 2 in. from the bottom, or a bend may be fixed on the dip pipe to turn the water towards the front of the boiler, as shown in fig. 408.

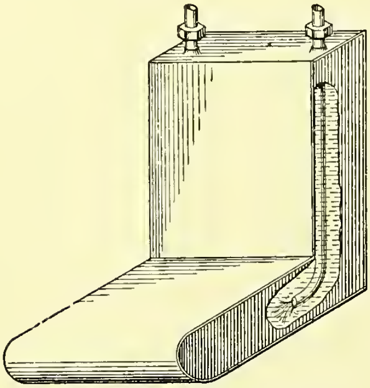


Fig. 408.—Method of Connecting Return Pipe to Boot Boiler

Independent Boilers,[1] as previously stated, are indispensable in mansions, hotels, public institutions, &c., where large quantities of hot water are daily required. They are economical as regards fuel, and do not require much attention, and may be fixed either in the kitchen alongside the cooking range, or in the basement. This latter position is generally chosen in hotels and public institutions.

The materials generally used are wrought iron and copper, the former where temporarily hard water is used, and the latter in soft-water districts. Where the boiler is made of copper, coke should not be used for fuel, as the gases evolved during combustion have a deleterious effect upon the copper, rapidly destroying it. There are various shapes of boilers, but the most common and useful forms are the cylindrical and the conical. The latter is usually adopted for wrought-iron boilers, and the former for copper boilers.

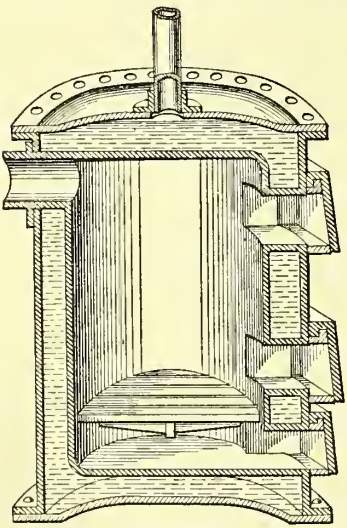


Fig. 409.—Independent Boiler with Waterway Top and Bottom

Wrought-iron boilers have their various parts riveted together, except in the case of small boilers, which are usually welded, and where hard water is used provision must be made for removing the scale. Fig. 409 shows a boiler so constructed as to render it easily accessible for cleaning. The top and bottom may be entirely removed and replaced without difficulty, as they are provided with nuts and bolts, and the joints made tight with rubber, or hemp and red-lead. Where copper boilers are used no access is necessary, as they would never be used except for soft waters, on account of the heavy initial cost.

The flow pipe should always be taken from the top, and the return pipe carried as near the bottom of the boiler as possible, as in the case of boilers in ranges, and it is advisable to fix gun-metal unions on these pipes in order to enable the boiler to be disconnected easily for cleaning. The connections are

[1] For illustrations of different boilers see Section XII.

generally made by riveting flanges, tapped to receive the required size of pipe, to the boiler. Each boiler should be provided with a sludge-cock connection at the bottom, for emptying and flushing purposes, not less than $\frac{3}{4}$ in. in diameter.

Care should be taken in using the fire irons for breaking up the coal or coke that no damage is done to the boiler; many boilers are ruined in one or two years through rough usage of this kind, and this is especially the case with copper boilers, owing to the softness of the metal.

CHAPTER VII

BOILER EXPLOSIONS AND SAFETY VALVES

Boiler Explosions are often attended with loss of life or serious personal injury, and it is imperative that precautions should be taken to guard against them in all hot-water systems. Speaking generally, there are four causes to which they are ascribed:—

1. The stoppage of the circulation pipes by ice.
2. The stoppage of the circulation pipes by encrustation of the deposit of lime from temporarily hard water.
3. The closing of stop cocks, which have been fixed on the flow and return pipes.
4. The sudden discharge of water into a boiler, the water from which has been previously evaporated.

The last-mentioned is a doubtful cause; and at this point it will be advisable to distinguish between **a "fracture" and a "burst"**. It is quite possible in the case of a cast-iron boiler for a "fracture" to occur from the fourth cause, but it would be almost impossible for steam to be generated suddenly in such quantities as to attain a pressure sufficient to burst the boiler; for one, at least, of the circulation pipes is open, as it discharges water into the boiler.

In several instances brought before the writer's notice the front and bottom plates of the boiler were fractured, but no part of the boiler had been forced off; the fractures thus caused were undoubtedly due to the sudden cooling of the plates when the water entered the boiler. If copper or wrought-iron boilers were exposed to the same conditions, it is extremely doubtful if any fracture would occur, as these metals possess great tenacity and elasticity.

Encrustation.—It is also a disputed point whether the second cause has ever been directly responsible for a boiler explosion. The encrustation, as previously explained, goes on very slowly, and the choking of the pipes will readily be observed by the noises emitted when the bore has been considerably reduced, and by the escape of air and steam along the circulation pipes Again, the deposit takes place more quickly in the flow than in the return pipe, as the hottest water under normal conditions passes through this pipe first; and not until the water in the cylinder is thoroughly heated does the

water passing down the return pipe leave much deposit. It is therefore obvious that even if the flow pipe is entirely blocked the return pipe would be still open, and the warning noises would be heard as before.

Occasionally lead pipes used for hard water are melted by the heat of the fire where they leave the boiler and pass across the flue, owing to the encrustation acting as a non-conductor between the fire and the water.[1]

Frost is the most fruitful cause of boiler explosions, especially in houses which are closed for some time during the winter months. The boiler and circulation pipes are more or less exposed, so that the water in them freezes during cold weather. When the house is re-opened in similar frosty weather the kitchen fire is lighted, the ice in the boiler is melted if the boiler is intact, and the water is gradually raised in temperature, and a portion of the ice in the flow and return pipes disappears; but the ice, being a bad conductor of heat, melts so slowly that several hours after the lighting of the fire an explosion may occur. This explosion is due to the heated condition of the water, which generates such a pressure in the boiler as effectively prevents the formation of steam, though, when the explosion occurs, the water in the boiler becomes partly converted into steam owing to the great reduction in pressure. Great care should be taken to avoid exposing any portion of the circulation pipes to the action of a cold wind, such as they might be subjected to in passing through a cavity wall.

With regard to the third cause, **stop cocks** should not on any account be fixed on circulation pipes. The usual excuse for fixing them is that the boiler may be removed for repairs, &c., without emptying the system, but this reason is not sufficient justification for their introduction, and the practice cannot be too strongly condemned. They are always open to interference by persons who do not understand their purpose or the grave danger incurred by tampering with them. For instance, the workmen may be so negligent as to leave the stop cocks turned off after re-packing the boiler unions—a piece of work, however, which does not always necessitate the emptying of the boiler.

If the boiler is provided with a draw-off pipe, it is an easy matter to ascertain if the boiler and circulation pipes are free from ice by opening the cock. If a draw-off is not provided, the cylinder must be emptied and the flow and return pipes must be disconnected from it; then if air is forced into one of the pipes, water will escape from the other provided that there is a free passage.

Safety Valves.—In the case of steam boilers it is essential to provide for the automatic release of steam when the pressure reaches a point above the safe-working limit of the boiler. This rule should also be observed in dealing with domestic hot-water supply boilers. The method usually adopted consists in the connection to the boiler of a safety valve, which allows of a discharge when the pressure in the boiler rises above a certain point.

[1] A case occurred in the writer's experience, where the circulation pipes were air-bound and no water passed into the boiler, with the result that the lead pipes near the boiler were melted, allowing an escape of water, which caused the occupants of the house to imagine that the boiler had exploded.

The first type of safety valve to be considered is known as the **dead-weight safety valve**, one form of which is shown in fig. 410. The principle upon which it is based is the counterbalancing of the internal pressure, due to the head of water on the boiler at A, by weights placed on the cone B. A column of water 1 in. square and 1 ft. high weighs ·434 lb. Assuming that the head of water at A is 60 ft., and that the area exposed to it is equal to a circle $\frac{1}{4}$ in. in diameter, then the weight required to counterbalance this pressure will be

$$60\,(\text{ft.}) \times \cdot 434\,(\text{lb.}) \times \pi R^2$$
$$= 60 \times \cdot 434 \times \frac{22}{7} \times \frac{1}{8} \times \frac{1}{8} = 1{\cdot}27\ \text{lb.}$$

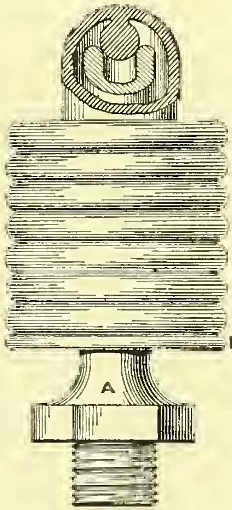


Fig. 410.—Sectional View of Dead-weight Safety Valve

In actual practice this weight would be nearly doubled, to guard against a slight accumulation of pressure above the normal due to the generation of steam, &c., and also to keep the valve steady. This form of valve is very reliable; it is made in gun metal, and the seating at A, and also the valve itself, are occasionally silver-plated to preserve the faces.

Another reliable form of safety valve (fig. 411) is the same in principle, but the details of construction are somewhat different. The weights in this type rest upon a gun-metal spindle, which transmits the weight to a valve at its lower extremity. The valve is provided with a fibre washer, resting upon a rounded seating.

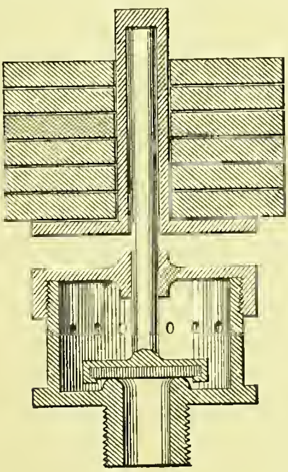


Fig. 411.—Section of Dead-weight Safety Valve

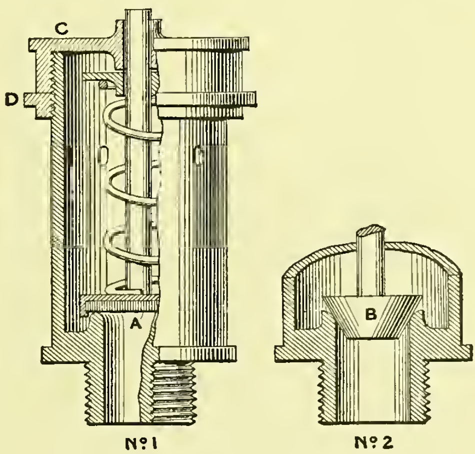


Fig. 412.—Two Sections of Spring Safety Valve

There are other forms of the dead-weight safety valve, but the two described are the most generally adopted.

Spring Safety Valve.—The second type of valve (fig. 412) depends for its efficiency upon a spring enclosed in a cylindrical brass chamber. When the

cap C is in position, the spring is compressed and forces the top of the valve against a prepared surface, thus making a water-tight joint. The valve may be provided with a rubber or fibre washer as at A, No. 1, or the surface may be ground into the seating as at B, No. 2, obviating the use of any washer. The cap C provides an arrangement whereby the compressive force of the spring may be increased or decreased by screwing or unscrewing the cap. The locking nut D serves to fasten the cap in position. The perforations around the cylinder permit water or steam to escape when the valve is raised by excessive pressure.

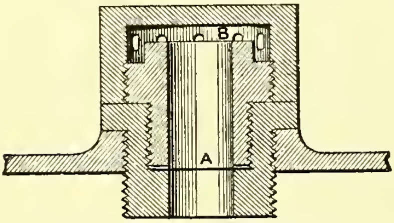


Fig. 413.—Disc Safety Valve

Disc Safety Valve.—A third type, known as the disc safety valve (fig. 413), consists of a disc A, of mica, copper, or zinc fixed between two surfaces in such a manner that the central portion is exposed to the pressure of the water in the boiler on the lower side, and to that of the atmosphere on the upper side. When an abnormal pressure occurs in the boiler, the disc is unable to sustain it, and is *forced out of position*, permitting the escape of water or steam through the holes in the cap B. This valve is arranged to fit in the top of the boiler without projecting much above the surface.

The objection taken to this form of valve, in the case of an apparatus supplied with temporarily hard water, is that the disc is liable to become coated with scale; but it will be observed that below A a quantity of air will collect when the boiler is filled with water; this will be absorbed by the cold water, but will be constantly replaced by the air or gases which are driven off when the water is heated. It is also an easy matter to clean the valve at times when the scale is being removed from the boiler. The writer considers this valve to be very reliable and to be less expensive and less likely to get out of order than any other kind for domestic boilers. The best metal to use for the disc is copper, about 22 B.W.G., with 1 in. diameter exposed to the pressure.

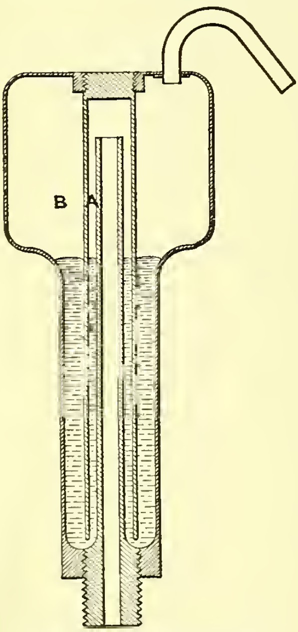


Fig. 414.—Mercury Safety Valve

Mercury Safety Valve.—In another type (fig. 414) a column of mercury counterbalances the head of water on the boiler. The mercury is held in a kind of trap A, and when there is an increase of pressure in the boiler the mercury is forced into the receiver B, and the water escapes past it and through the outlet pipe at the top of the dome. The receiver prevents any of the mercury from passing out of the appliance. Mercury is about thirteen and a half times as heavy as water, and upon

this of course depends its counterbalancing power. The disadvantage of this appliance is that a slight increase of pressure, such as may be caused by the sudden closing of a tap, is sufficient to force the mercury trap and permit the discharge of a quantity of water. The valve is also bulky and difficult to fix on the boiler.

Fusible Plug.—The appliance known as a fusible plug (fig. 415) is a gun-metal cylinder filled with a metal which melts at a temperature a few degrees above the boiling-point of water, usually about 216° to 220° F. When the communication between the boiler and cylinder is stopped through any cause, the water in the boiler increases in temperature and expands, causing an increase of pressure, which raises the boiling-point; and when the temperature reaches 216° to 220° F. the metal plug melts and relieves the pressure. These plugs should be fixed in the tops of boilers near their fronts, and clear of any brickwork or ironwork. If the inside of the gun-metal cylinder is not tinned, the plug is liable to become loose, and cause a leakage, owing to its rate of expansion and contraction differing from that of gun metal. These plugs are by no means as reliable as a good type of safety valve, and, where temporarily hard water is used, the bottom face of the plug may become coated with scale, which acts as a non-conductor and prevents the heated water from coming in contact with the fusible metal.

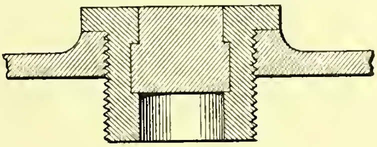


Fig. 415.—Fusible Plug

The position of safety valves has from time to time evoked considerable discussion. One plan is to fix the valve in front of the chimney breast, another to one side of it, while a third is to connect it to the flow or return pipe, several feet from the boiler. In the two first arrangements a special pipe about $\frac{3}{4}$ in. diameter connects the valve to the boiler. The writer has made a special study of this question, and, combining the experience of a number of the highest authorities with his own, is certain that the right place for a safety valve is directly on the boiler and not away from it. Fig. 416 shows an ordinary dead-weight safety valve fixed directly on the boiler, and enclosed by a metal box to prevent soot and ashes from affecting its efficiency. The cap A is sufficiently heavy to make the case dust-proof with the aid of asbestos packing, and, as the cap fits loosely around the sides of the case, it is easily lifted by a slight pressure from the inside.

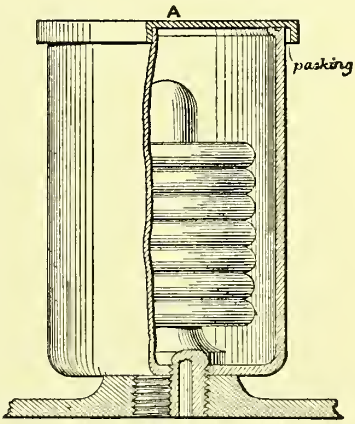


Fig. 416.—Right Position for Safety Valve

Sometimes the valve is fixed on the flow pipe where it leaves the chimney breast, but this is not a desirable arrangement either for hard or soft water, as that part of the flow pipe between the valve and the boiler may become choked with ice, and remain ice-bound, after the kitchen fire

has been lighted, a sufficient time to cause an explosion. The same drawback applies to a safety valve connected by a separate pipe to the boiler.

CHAPTER VIII

CYLINDERS AND TANKS

Size of Cylinders.—The size of the cylinder must be regulated by the heating power of the boiler to which it is connected. If the cylinder is too large for the boiler, the water will take a long time to heat, and a hot bath cannot be had within one and a half or two hours after the lighting of the fire. In houses it is a great convenience to be able to draw hot water soon after the kitchen fire has been lighted, and in many cases a small cylinder rapidly heated is preferred to a larger cylinder. The latter certainly provides for the storage of a greater volume of water, but if the boiler is the same in each case the smaller cylinder will give the hotter water throughout the greater part of the day. The following table will be useful in this connection:—

Sizes of Boilers and Cylinders, and Number of Draw-off Taps

Kind of Boiler.	Size of Fire.	Capacity of Cylinder in gallons.	Size and Number of Draw-off Taps.
Box type	8 or 9 in.	25	two ½ in. and one ¾ in.
,, with arched flue ...	9 to 12 ,,	30 to 40	,, ,, two ,,
Boot	9 ,,	40	,, ,, ,, ,,
,, ...	11 ,,	50	,, ,, three ,,
,, ...	12 to 14 ,,	50 to 60	four ,, ,, ,,
Independent	36 in. × 16 in. diam.	60	,, ,, four ,,
,, ...	44 ,, 18 ,,	70	five ,, five ,,
,, for hotels, &c.	48 ,, 18 ,,	100	six ,, six ,, *
,, ,, ,,	54 ,, 21 ,,	150	twelve ,, eight ,, *
,, ,, ,,	68 ,, 24 ,,	200	eighteen ,, fourteen ,, *

Contents of Tanks and Cylinders.—The cubical contents of a rectangular tank are obtained by multiplying the length by the breadth by the depth, or L × B × D. As there are $6\frac{1}{4}$ gal. in 1 cu. ft., the contents of the tank in gallons will be: $L \times B \times D \times 6\frac{1}{4}$. Thus the contents in gallons of a hot-water tank 2 ft. 6 in. × 2 ft. × 1 ft. 9 in. will be:

$$\frac{5}{2} \times \frac{2}{1} \times \frac{7}{4} \times \frac{25}{4} = 54\tfrac{11}{16} \text{ gal.}$$

It is occasionally necessary to determine one measurement when the number of gallons and the other dimensions are given. Thus, to find the depth of a rectangular tank to hold 35 gal., the length being 2 ft. 6 in. and the breadth 1 ft. 6 in.:

$$\text{Depth} = \frac{\text{Gallons}}{L \times B \times 6\frac{1}{4}} = \frac{35}{2\frac{1}{2} \times 1\frac{1}{2} \times 6\frac{1}{4}} = 1 \text{ ft. 6 in. (approx.).}$$

* Or more, if the fire is well attended to.

The weight of the contents of the tank in pounds may be obtained by multiplying the number of gallons by 10, as 1 gal. of water at 60° F. weighs 10 lb.

The capacity of a cylinder in gallons may be found by multiplying the area of the circular cross section by the vertical height, and this again by $6\frac{1}{4}$.

For example: A cylinder is 4 ft. 6 in. high and 2 ft. 3 in. diameter; the capacity in gallons $= \pi R^2 \times H \times 6\frac{1}{4}$ (where $\pi R^2 =$ the area of the circle, H the height of the cylinder, and $6\frac{1}{4}$ the number of gallons per cubic foot).

$$\text{Capacity} = \frac{22}{7} \times \frac{9}{8} \times \frac{9}{8} \times \frac{9}{2} \times \frac{25}{4} = 111 \cdot 87 \text{ gal.} \quad \text{Weight} = 1118 \cdot 7 \text{ lb.}$$

To find the diameter of a cylinder to hold a given number of gallons, the height being given. Example: A cylinder holds 50 gal. and is 3 ft. 6 in. high; then its diameter will be

$$2\sqrt{\frac{\text{Gallons}}{\pi \times H \times 6\frac{1}{4}}} = 2\sqrt{\frac{50}{\dfrac{22 \times 7 \times 25}{7 \times 2 \times 4}}}$$

$$= 2\sqrt{\frac{50 \times 7 \times 2 \times 4}{22 \times 7 \times 25}} = 2\sqrt{\frac{8}{11}} = 2\sqrt{\cdot\dot{7}\dot{2}} = 2 \times \cdot 8528$$

$$= 1 \cdot 705 \text{ ft.} = 1 \text{ ft. } 8\tfrac{1}{2} \text{ in. (approx.).}$$

The height of a cylinder whose diameter and contents are known may be found in a similar way; thus, assuming the diameter to be 2 ft. and the capacity 75 gal., the height will be

$$\frac{\text{Gallons}}{\pi R^2 \times 6\frac{1}{4}} = \frac{75}{\dfrac{22 \times 1 \times 1 \times 25}{7 \times 1 \times 1 \times 4}}$$

$$= \frac{75 \times 7 \times 4}{22 \times 25} = \frac{42}{11} = 3 \text{ ft. } 9\tfrac{3}{4} \text{ in. (approx.).}$$

It is always advisable in these calculations to keep the dimensions in feet.

Materials.—Cylinders are made of copper or galvanized sheet iron. Copper is seldom acted upon to any appreciable extent by the various kinds of potable water, and it is for this reason, and for its durability, that it is largely used for cylinders. For the same reasons comparatively thin metal may be used, the thickness depending upon the size of the cylinder and the head of water it will be required to sustain. The strength lies generally between 22 and 14 B.W.G.

Sheet iron galvanized is probably the best metal to use in districts where the water is temporarily hard. Under such conditions access holes, large enough for a workman to insert his arm and work in comfort, have to be provided for removing the scale from the cylinder. If copper were used it would require to be of great thickness (not less than $\frac{1}{4}$ in.) to withstand the hammering and chipping necessary to remove the scale. The deposit of lime would prevent the water having any action upon the iron for some considerable time, but it is found in practice that the bottom of

the cylinder becomes gradually perforated by the rusting of the iron in various places, and this is sometimes most noticeable at the rivets. The thickness of galvanized-iron cylinders is seldom more than $\frac{3}{16}$ in.

Access Lids and Unions.—Fig. 417 shows a galvanized-iron cylinder with access lid, and tapped bosses riveted to it to receive the necessary connections. The connections must be ordered to suit the special circumstances of each case. In the illustration A is for the cold supply, B for the primary return, C for the primary flow, D for the expansion pipe, and E for the secondary return. The primary flow is often connected to the cylinder a few inches only above the primary return, and is turned up inside the cylinder to about half the height. A connection for a secondary return is not always required.

The connections to copper cylinders are made to screwed bosses, each provided with a cap and lining, the bosses being riveted and brazed to the cylinder, and the lining or tail of the union being either prepared for soldering to lead, or screwed or tapped to receive iron or copper pipes. All unions in connection with the cylinder should be of the "ground-joint type" advocated for boilers, as this adds very little to their cost, but much to their efficiency.

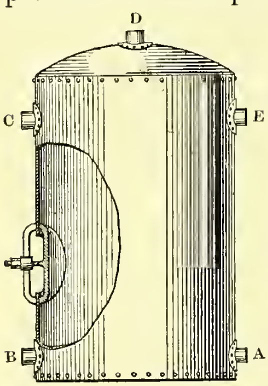


Fig. 417.—Cylinder with Access Lid

Collapsing of cylinders is due to the entrance of steam which, when it condenses, forms a partial vacuum, and the atmospheric pressure on the outer surface of the cylinder forces the sides in, causing what is known as a "collapse". This may be brought about if, in consequence of the stoppage of the cold-water supply and expansion pipes through frost or other cause, the cylinder is emptied by evaporation, or by a draw-off fixed on the pipes between the boiler and cylinder, or attached to the cold supply to the cylinder at a low level, or if the contents of the cylinder have been ejected in geyser-like motions by steam generated in the boiler. The water in the boiler now becomes converted into steam, and, passing into the cylinder, drives the air and water out through any tap which may be opened. When at night the boiler fire is allowed to go out, the steam condenses, and, there being no aperture for the admittance of air to equalize the pressure inside and outside the cylinder, the external atmospheric pressure forces the sides in. Copper cylinders are more liable to collapse than galvanized-iron cylinders of the same size, owing to the copper being thinner and more pliable, but corrugated copper cylinders, which are much stronger than the plain cylinders, are now made.

A case was recently brought to the writer's notice of a collapse which occurred under peculiar circumstances, the cylinder being of copper. A workman was sent to take out a fusible plug from a kitchen boiler, and to insert an ordinary wrought-iron one in its place on account of leakage. The hot-water system did not possess any cold-supply "control" cock, or a "draw-off" for emptying purposes, and as the emptying of the system would have necessitated the removal of the contents of the cylinder by siphonage, the

workman stopped the end of the expansion pipe with a cork, treated the termination of the cold supply in the tank in a similar manner, and forthwith proceeded to take out the fusible plug from the boiler. Immediately the plug was removed from the boiler, water began to flow from the hole, and the workman, after taking up some bucketfuls, sent his mate to see if the corks were intact. The mate, after ascertaining that this was the case, casually inspected the cylinder fixed on the first floor, and found it crumpled to the shape of a half-opened concertina. This was due to the weight of the column of water between the cylinder and boiler being greater than the sustaining power of the cylinder to external pressure. The water escaping at the boiler tended to form a vacuum in the cylinder, thereby reducing the internal pressure below that of the external atmospheric pressure.

To prevent the collapsing of cylinders an appliance known as a vacuum valve is fixed directly on the cylinder (fig. 418). This, while preventing the escape of water, permits air to enter the cylinder when the pressure on the top of the valve A is less than the atmospheric pressure on the bottom of the valve. In this illustration a "dead-weight" safety valve is shown above the vacuum valve, the object of fixing the safety valve being to allow for a release of the pressure in the cylinder should the expansion pipe and the cold-supply pipe become blocked with ice, or in any other way stopped, whilst the pipes between the boiler and cylinder remain open. Vacuum valves can be obtained without the safety-valve addition, but as there is not much difference in the cost it is advisable to use the combined fitting.

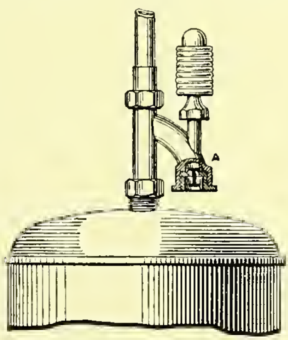


Fig. 418.—Safety and Vacuum Valves connected to Cylinder

Tanks.—The materials used for tanks are copper, galvanized iron, wood with lead lining, and slate. In the tank system, copper or galvanized iron would be used for the closed hot-water tanks, according to the character of the water supply; but for open cold-supply tanks galvanized iron or lead-lined wood is used for hard water, and slate or tinned copper in localities where the water has a plumbo-solvent action.

Cold-supply Tanks.—The size of the cold-supply tank will depend upon the requirements of the establishment, the pressure of the water in the main, and the character of the supply as regards its constancy or otherwise. If the supply is intermittent, a separate tank for supplying the hot-water system is often provided, or as an alternative a single storage cistern is used and the cold supply to the hot-water system is connected to it as near the bottom as practicable, while the pipe supplying the cold-water taps is connected about 4 or 6 in. higher. If the main supply is shut off, and the water in the cistern is drawn off, the supply at the cold-water taps will cease before there is any deficiency in the hot-water system. To prevent any danger, no more water should be drawn from the hot-water taps until the cistern has been refilled. Where the supply is constant a single cistern with the connections as described above is generally provided except in the smallest houses, where the cold-water taps are sometimes supplied from the main

service pipe, and a cistern is provided for supplying the hot-water system only.

Rectangular Closed Hot-water Tanks of galvanized wrought iron are made in stock sizes ranging in capacity from about 20 to 100 gal. The thickness of the metal used for small tanks is 16-gauge, 14-gauge, 12-gauge, or $\frac{1}{8}$ in., and tanks of these strengths are tested to 1, 3, 4, and 5 lb. per square inch respectively. Tanks of $\frac{3}{16}$-in. plate, tested to 10 lb. per square inch, are also stocked by some makers, and tanks of $\frac{1}{4}$-in. plate, tested to 15 lb. per square inch, are quoted but not always kept in stock. It is unwise to use metal less than $\frac{1}{8}$ in., even if the normal pressure is less than 5 lb., and it is always better to use $\frac{3}{16}$-in. plate. Each tank has an access hole fitted with a bolted or bridge cover, and a rubber ring is supplied for making a water-tight joint.

CHAPTER IX

PIPES AND FITTINGS

Pipes.—The material used for the pipes required in hot-water systems is usually decided by cost, situation, and the character of the water they are intended to convey. Lead, iron, and copper are the metals generally used.

Galvanized-iron pipe is only suitable where water is not of a soft or plumbo-solvent character. It is not advisable under any circumstances to use plain wrought-iron pipes. The difficulty attending the use of galvanized-iron pipe is that there are always some parts unprotected by the galvanizing, as it is almost impossible in manufacture to ensure the entire coating of the interior of the pipe and of the connections, such as tees, elbows, &c. Upon the unprotected parts the water, if well aerated, readily acts, its effect being very pronounced in the case of soft water, but scarcely appreciable in that of hard water owing to the deposit which soon forms on the interior of the pipe. As in hard-water districts it is necessary periodically to remove scale or deposit from the pipes, and an amount of hammering is necessary after they are uncoupled, galvanized iron is undoubtedly the best material for such water.

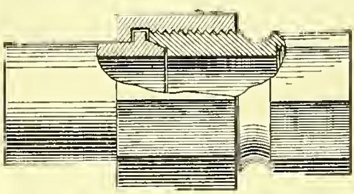


Fig. 419.—Section and Elevation of Union with Ground Faces

The joints between the various lengths of pipe are made by screwing the ends and inserting them in tapped tees, elbows, or sockets, according to the requirements of the situation. Where required to be disconnected, gun-metal unions should be provided of the "ground-joint" type, as shown in fig. 419, as they are much more easily made water-tight than the long screw and back nut, which are often difficult to uncouple and afterwards to render water-tight.

Lead is largely used in the North and Midlands for hot water on account of its comparative cheapness, and the readiness with which it can be bent

to suit special positions. It also lends itself to secure jointing, and is a poor conductor of heat. One great disadvantage, which renders it unsuitable for positions where there is great variation in temperature, is that its ratio of expansion by heat is high, and slightly in excess of the contraction which occurs during a reduction in temperature, as the expansion is assisted, and the contraction resisted, by the pressure of the water. A permanent enlargement of the pipe is thus caused, and consequently a reduction in the thickness of the metal. Lead pipes in long lengths bulge out of line, or sag in places where there is insufficient support, and as a result of the attenuation fractures often occur in the pipes in the immediate neighbourhood of joints, especially if the workman has forced his shave-hook into the pipe farther than is necessary. The bends in the pipe are also a source of weakness in this respect, especially if made to a small radius, and it is always advisable for other reasons also to make the bends to as large a radius as practicable. The joints should be "wiped plumbers' joints", and no other method of jointing should be used for uniting lead to lead, or to brass or gun metal, and care should be taken that the ends of the pipes are properly tinned before the joint is wiped.

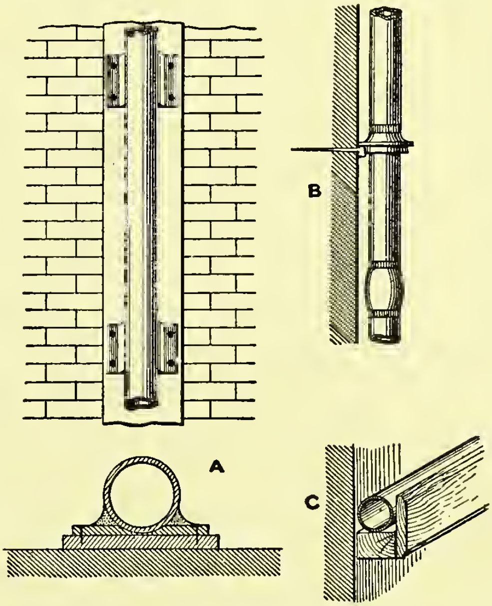


Fig. 420.—Joints and Fixings for Lead Pipes

Lead pipe should always be substantially supported. It is unsuitable for long vertical lengths owing to the difficulty experienced in supporting it rigidly in position, on account of the degree of expansion which takes place in the pipe. If lugs are soldered to the pipe and screwed to a board fixed to the wall, as in A, fig. 420, the pipe between the lugs bulges out, and there is every probability that the screws will in time be loosened. A method of fixing which the writer has adopted with some success is shown at B, fig. 421, and consists of an iron ring spiked to admit of its being driven into the wall. The pipe passes through the ring, and a lead flange resting upon it is soldered to the pipe, and this, whilst supporting the pipe, does not interfere with its expansion. These supports should be fixed not more than 3 ft. apart, and where lugs are soldered to the pipe they should occur every 1 ft. 6 in.

Where fixed on an inclined or horizontal plane the pipe should rest upon a fillet firmly secured to the wall C, fig. 420, and no further stay is necessary except to prevent the pipe falling off the support. Where it is necessary to carry two or more pipes, they may be placed one over the other on the same support, but pieces of wood $\frac{1}{2}$ in. thick should be inserted

between them to allow free expansion, or each pipe may be supported on a separate fillet.

Where the water is of a plumbo-solvent character *tin-lined lead pipes* are sometimes used, but they have not proved successful in the writer's experience, as the lead becomes invariably exposed owing to longitudinal cracks occurring in the tin lining.

Copper is the most suitable metal for use with soft water, and as copper connections can now easily be made perfectly secure and water-tight, there is no reason why this metal should not be more generally adopted. It is advisable to have the pipe coated with a thin film of tin inside and outside, with the object of preventing any action which might take place where soft water is used, and also to give the pipe a good appearance. The strength of copper required for the purpose need not exceed from 12 to 16 B.W.G., according to the size of the pipe.

Copper pipe may be bent with almost the same ease as lead pipe. The tube should first be "softened" where the bend is required by heating to about 800° F. and quickly cooling in water. The part thus treated should then be filled with resin or molten lead, or a mixture of resin and bitumen, which should be allowed to cool before the pipe is bent; after bending, the core can be melted out. The core prevents the pipe flattening, and gives it a round finished appearance. All bends should be made to a large radius, to reduce friction on the flow of water through the pipe.

The joints in copper pipes, of the strengths previously given, were formerly made by wiping plumbers' joints around the ends, or sweating sockets or tees on the pipe with fine solder. These are very unsatisfactory methods, and invariably result in the failure of the joints at one or more points on the system, owing to expansion and contraction, and a galvanic action which, in the presence of water of a slightly acid character, is set up between the solder and the copper, destroying the tinned surface on the latter metal, and permitting a leakage to occur. The best method is to screw the ends of the pipe with dies, arranged to cut a much finer thread than those of the "gas" type used for iron pipes. This fine thread is specially adapted for light copper pipes, and has a pitch between those used for brass and iron. Fittings can be obtained with the same pitch of thread and correspondingly light in structure. The pipes, before being screwed together, should be tinned in the fittings (female ends) and on the male ends of the pipe. The fittings can be obtained ready-tinned, but the thread on the pipe requires tinning by the plumber. If zinc chloride is used for the purpose, or any acid, it must be thoroughly washed off and the end covered with powdered resin before securing the pipes together, as, if this precaution is not taken, there is every possibility of galvanic action setting up when the water comes in contact with the salt left on the joint, and leakage may occur. This occurred extensively on a large system which the writer was called upon to inspect, after it had been in working order for just over one year.

Fig. 421, A, shows the detail of the screwed joint, and, as it is made while the pipes and tee are at a temperature above the melting-point of fine solder, it offers double security against leakage. If necessary the

branch may be curved to suit the direction of the flow. Fig. 421, B, shows a connection which is used in the case of copper pipes for the top of the cylinder, and the union joints of which are of the "ground" type. If a "four-way" is not required, a tee of the same pattern can be obtained.

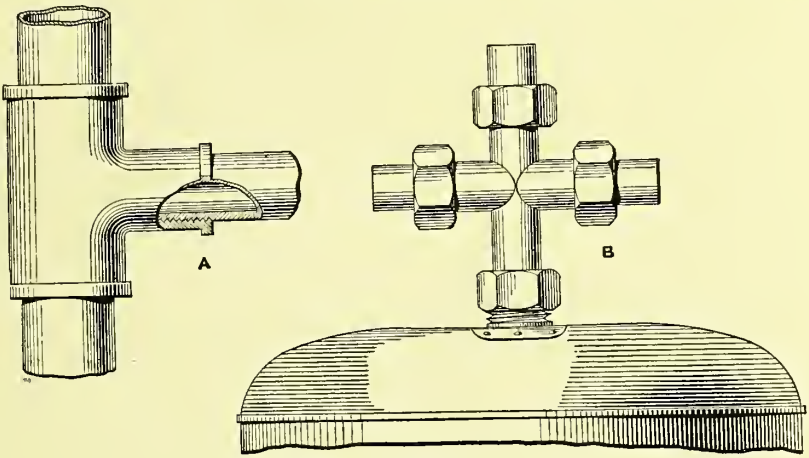


Fig. 421.—Fittings and Joints for Copper Pipes

The branches may be curved in the direction of the flow of the water to reduce friction. Such a connection is suitable where lead pipes are adopted, as wiped joints at this point very often give way.

If copper pipes are fixed in horizontal or vertical positions, and exposed to view, special **gun-metal clips** may be used to support them, fixed to the wall by screws; but copper and iron pipes do not require as much support as lead pipes when fixed horizontally, owing to their greater rigidity and tenacity.

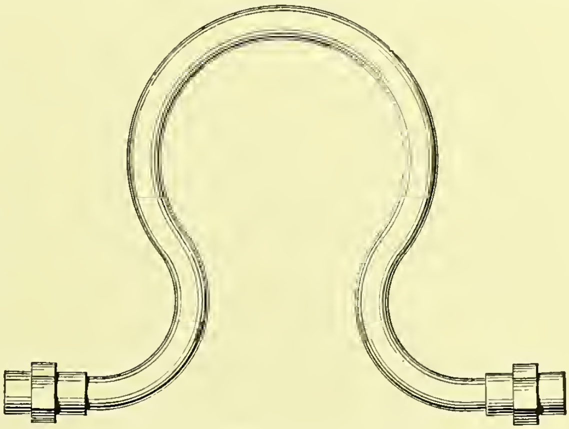


Fig. 422.—Bent Pipe for Expansion

The question of **expansion and contraction** requires consideration in the cases of copper and iron. Where the pipe is straight for only a few feet in length before it changes direction, no special provision need be made, but where long lines of copper or iron pipe are used, though the rates of expansion and contraction are not so great as in the case of lead pipe, some arrangement is necessary to deal with these in such a way that no damage shall occur to the various branches taken from the pipes. One method consists in the formation of a loop in the pipe, as shown in fig. 422. Owing to the elasticity of the metal, the loop opens and closes when contraction and expansion

affect the length of the pipe. The loop should be fixed horizontally to prevent any accumulation of air. If the pipe is of considerable length, with numerous branches taken from it, two or more of these loops may be required, the number and position being governed by the requirements of every case, and care being always taken to fix them in such positions as will effectively prevent any breakage between the branches and the main pipe. As this arrangement considerably retards the flow of the water through the pipes, the number of loops introduced should be as few as possible.

The second method consists of a gland arrangement (fig. 423), which slides backwards and forwards in a specially constructed socket. The weak point in this appliance is the packing of the gland, which requires continual attention to prevent leakage, and consequently this method is not so reliable as the first.

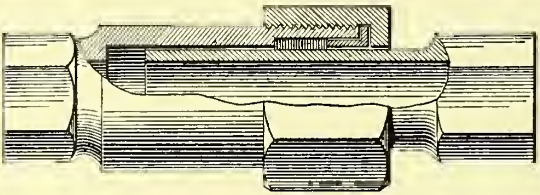


Fig. 423.—Expansion Joint

Under no circumstances should hot-water pipes be secured by clips or stays in such a rigid manner as will interfere with their expansion and contraction.

Fittings, such as stop cocks, bib cocks, unions, tees, bends, &c., should be made of the best gun metal, except where wrought-iron pipe is used, when the tees and bends are of the same metal as the pipe. Stop cocks[1] should be of the "full-way" pattern, so that the flow of water through the valve may be impeded by friction as little as possible. Those of the sluice pattern known as "Peet" valves are most suitable. They may be obtained ready for connecting to lead, copper, or iron pipes. Bib or stop cocks of the "plug" type[1] are a source of weakness on a hot-water supply system. Leakage at the plug very often takes place, and the sudden closing of bib cocks causes water-hammer or ram in the pipes to which they are connected, and if the pipes have one or more bends the sudden pressure each time the tap is quickly closed sometimes causes fractures at the weakest parts, usually the bends; to obviate this, screw-down valves[1] should be used. The hot and cold taps should be labelled so that the water required may be obtained without confusion and inconvenience.

When arranging the pipes of hot-water supply systems, the various routes to be followed should be carefully chosen, so that the pipes may be easily accessible, and the branches to points of hot-water delivery may be as short as possible, as long "dead" lengths of pipe, holding cold water, are objectionable and wasteful.

The circulation pipes should, whether of "primary" or "secondary" systems, have a slight rise in the case of the flow, or fall in the case of the return pipes, and horizontal lengths should be avoided. At all high points air pipes or valves must be provided for the relief of any air or gas which may accumulate. Dips or traps should be avoided as far as possible on the circulation pipes and on the branches for the supply of hot

[1] See Section V, Chapter X

water to the fittings. All pipes laid under floors, or in inclined positions on the surfaces of the walls, should be adequately supported, to prevent sagging. The number of bends should be as few as possible, and such as are necessary must have a large radius. No elbows should be used in the case of copper or iron pipes, as copper may be bent to suit most conditions, and iron bends to a large radius are commonly manufactured.

The primary flow and return pipes between the boiler and cylinder should be as short as possible, to minimize friction, and also radiation of heat. The flow should always start vertically from the top of the boiler, and no bend should occur nearer than 1 ft. 6 in. to the boiler. It is advisable, where lead pipes are used, to let them into a groove in the brickwork at the back of the range, and cover them with fire-clay mortar to prevent the fire or flames from damaging them. No dips or traps should be formed on either the flow or return pipe. The pipes between the boiler and cylinder should not, under any circumstances, be less than 1 in. in diameter, and where the water is temporarily hard, and a plentiful supply of hot water is required, they should not be less than $1\frac{1}{2}$ in. or 2 in. in diameter.

The cold-supply pipe to the cylinder should be as straight as possible, and, before entering the cylinder at the bottom, it should have a dip or trap, not less than 18 in. deep, to prevent local circulation between the cistern and cylinder. The diameter of this pipe should be sufficient to allow hot water to be drawn at most or all of the hot taps at the same time. As a rule it ought not to be less than 1 in. in diameter, and for larger supplies it must be $1\frac{1}{4}$ in. or more.

A full-way stop cock should be fixed on the cold supply, as near as possible to the cylinder. It is also advisable to fix a similar cock on the secondary flow pipe near the cylinder, which should be closed at night to prevent the heated water in the tank and cylinder from being cooled almost to normal atmospheric temperature by the radiation which would take place from the pipes constituting the secondary system, and in some measure from the tank itself if the water were allowed to circulate. These stop cocks should all be so labelled that they may readily be identified.

The relative capacity of pipes may be obtained by comparing the squares of their diameters. The size of pipe which will be required to supply a given number of fittings, each of which is connected to the main pipe by a branch of known size, may be ascertained by taking the square root of the sum of the squares of the diameters of the branch pipes.

Example.—What size of pipe is necessary to supply the following branches:—Two $\frac{3}{8}$-in., three $\frac{1}{2}$-in., four $\frac{3}{4}$-in., and one 1-in.?

$$\begin{aligned}\text{Required diameter of pipe} &= \sqrt{2(\tfrac{3}{8}^2) + 3(\tfrac{1}{2}^2) + 4(\tfrac{3}{4}^2) + 1^2} \\ &= \sqrt{\tfrac{9}{32} + \tfrac{3}{4} + \tfrac{9}{4} + 1} = \sqrt{4{\cdot}28} \\ &= 2 \text{ in. diameter (approximately).}\end{aligned}$$

The expansion pipe should also be taken as vertically as possible, and long inclined lengths, and also traps and dips, should be avoided. In hot-water systems supplied with temporarily hard water the deposit in this pipe is not nearly so large as that in the circulation pipes, and consequently no special means are needed for disconnecting it. The size of this pipe

will depend upon whether it forms the secondary flow, and the number of fittings to be supplied from it. If the secondary return is utilized for supplying some of the fittings, then the secondary flow and return may be of smaller diameter, as the supplies to the various fittings will be fed by two pipes instead of one. Should, however, all the branches be taken from the flow pipe, this must be considerably larger in diameter than the return, and may require to be 2 in., whereas the latter rarely needs to be more than $1\frac{1}{4}$ in.

Loss of Heat.—The actual amount of heat lost in any system by radiation from the pipes, cylinder, and tank depends upon: (*a*) the conductivity of the metal; (*b*) the length and diameter of the pipes and cylinder, and the size of the tank; (*c*) the difference in temperature between the water in the pipes and the air in their immediate vicinity; (*d*) whether the pipes, &c., are exposed to the cooling action of continuous currents of cold air, or covered to retain the heat. Of the three metals, lead, iron, and copper, the last is by far the best conductor of heat, having about five times the conductivity of lead, and about twice the conductivity of iron. This is an important consideration, which is sometimes not sufficiently taken into account. Where pipes conveying hot water are of great length, a large amount of heat is continually being radiated from the pipes, tank, and cylinder, and this occasionally necessitates the introduction of a boiler of higher heating power than the one originally installed.

Non-conducting Materials.—To minimize the loss of heat under such conditions the pipes are usually surrounded with some substance which is a bad conductor of heat. Some of the materials used for this purpose are given in the following table with their relative values as non-conductors of heat; wool felt, having the highest, is taken as the standard:—

Substance.	Non-conducting Value.	Substance.	Non-conducting Value.
Wool felt	1·00	Gas-house Carbon	·470
Mineral Wool (Slag Wool) ...	·832	Cork	·425
Saw-dust	·680	Asbestos	·363
Charcoal	·632	Coal Ashes	·345
Pine-wood	·553	Coke (in lumps)	·277

Wool felt can be obtained in strips suitable for wrapping pipes, or in sheets for covering tanks, &c. It is very effective, but is liable to harbour vermin, and is easily destroyed by fire. Mineral wool or slag wool, sometimes known as silicate cotton, ranks next in efficiency, and is manufactured from the slag from iron-smelting furnaces. It is formed into a kind of coarse wool by forcing jets of steam through it whilst in a molten state. It is entirely fire- and vermin-proof, and is undoubtedly one of the best substances for preventing loss of heat by radiation. It may be used with advantage as packing for hot-water tanks, and the difficulty of applying it to pipes which are not encased has now been overcome by fixing the material with wire to coarse canvas. Magnesite and some other earths are good non-conductors and are now much used. When cylinders are utilized for drying and airing linen, &c., and cupboards containing skeleton shelves are constructed around them for this purpose, no packing is required, but

where they are fixed in the basement they should be surrounded with a wood casing, leaving a space of 3 in. inside to be filled with slag wool. Attention to this matter will greatly add to the efficiency of the system. Asbestos is a suitable packing or wrapper for preventing the escape of heat, but expense prohibits its general adoption.

Faults and defects which occur in hot-water systems may be due to many different causes. The chief fault is the *insufficiency of hot water*, which may be ascribed to one or more of the following causes:—

1. Boiler heating surface too small, and incorrect arrangement of flues.
2. Connection of the flow from the boiler to the return connection in the cylinder.
3. Encrustation in the boiler and circulation pipes acting as a non-conductor and retarding the heating and circulation of the water.
4. Flow and return pipes connected near to each other in the boiler, dip pipe absent in the return pipe within the boiler, and the connection of cold supply to the boiler instead of the cylinder.
5. Excessive radiation of heat from the pipes, &c. (especially in the cylinder-and-tank system).
6. Air locks in primary or secondary circulation pipes.
7. Long draw-off or branch supplies, necessitating the recharging of the pipes with hot water each time the fittings are used.
8. Connection of the secondary return to the cylinder at too low a level.

Unpleasant noises are occasionally observed in hot-water supply systems, especially when the temperature in the boiler is greatest. Various causes, enumerated below, may be responsible for these:—

1. Boiler too large for the requirements, steam being generated more rapidly than it can quietly escape; it therefore makes its way through the flow pipe into the cylinder, and thence forces its way through the expansion pipe, driving out large quantities of hot water in "geyser" form.
2. Escape of air which has been imprisoned in the boiler by the flow pipe passing into the latter and forming an air space, or by the uneven setting of the boiler, the flow-pipe end being lower than the opposite end. This fault may develop after the fixing of the boiler, owing to insecure setting.
3. Partial stoppage of the circulation pipes (generally due to deposit of lime), which greatly retards the flow of water to and from the boiler, and causes large quantities of steam to be generated.
4. Dips in the circulation pipes, forming air traps, which greatly affect the circulation of water between boiler and cylinder.

CHAPTER X

HEATING WATER BY GAS AND OIL

Geysers.—It frequently happens that cottage residences are supplied with a bath and a cold-water service, but are devoid of any arrangement for supplying hot water. In such circumstances the tenant may provide

an apparatus requiring very little fixing, and easily installed, in the form of a gas water-heater known as a *geyser*. These appliances have upright cylindrical bodies which contain the water to be heated, and to these are connected supplies of gas and water. As the geysers will give hot water at very few moments' notice, and entail no expense when not in use, they are very suitable for such places as bungalows, sports' club dressing-rooms, public and railway-station lavatories, &c., and any place where the demand for hot water is of a sudden and intermittent character. If there is no supply of gas conveniently near such buildings, apparatus may be obtained provided with burners specially designed for the combustion of oil.

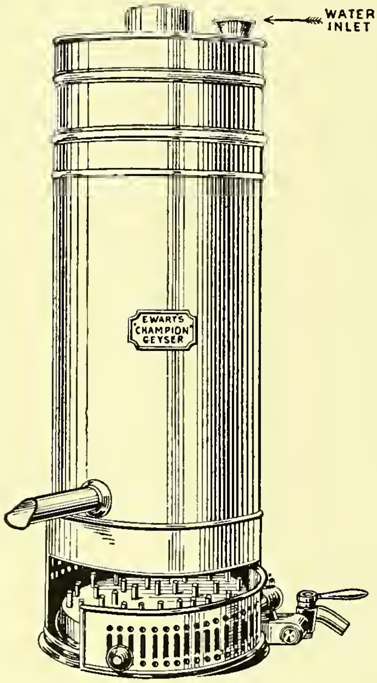


Fig. 424.—"Champion" Geyser

Geysers should be made entirely of copper with a tin lining where the water comes in contact with the metal, and the fittings should be of gun metal if those of copper are not suitable.

There are two principal types of geyser, the "open" and the "sealed".

In those of **the open type** the internal arrangements permit of the products of combustion coming in contact with the water, which is therefore polluted and rendered unfit for drinking or cooking, but may be used for bath and lavatory purposes, although not very satisfactorily. A geyser of this kind is only intended to raise the temperature of the water to 160° F. or thereabouts, and is not suitable for delivering boiling water. It may be used with advantage in hard-water districts, as the temperature of the water delivered is not sufficiently high to cause any appreciable deposit of the carbonate of lime in the water.

The open geyser shown in fig. 424 can be obtained in five different sizes. The first size will raise the temperature of 1 gal. of water 40° F. per minute. The temperature of the water can be further increased by diminishing the rate of flow through the apparatus. The gas supply pipe should not be less than ½ in. in internal diameter. The burner is so constructed that it may swing outwards to enable it to be lit without fear of an explosion taking place.

In **the sealed type** (fig. 425) the internal conduits through which the water passes while being heated are entirely enclosed, and consequently the products of combustion do not come in contact with the water. This type of geyser may therefore be utilized for supplying boiling water for cooking and other domestic purposes without risk of contamination, and is the type that should be adopted where possible in preference to that first mentioned. There are two classes of the sealed geyser, one of which is suitable for

sustaining any pressure up to 100 lb. per square inch, whilst the other is so constructed that no pressure is exerted upon the internal plates and fittings, the hot water flowing from one part of the apparatus at the same speed as the cold water entering at another point.

Generally speaking, **the burners** used in geysers are of the white-flame pattern, though there are many which possess the Bunsen burner. The latter is by far the more efficient as regards its heating power per unit of gas consumed, but the fumes given off by the white-flame burner are not so injurious as those from the Bunsen burner, which consist principally of CO and CO_2.

The following are the **two principal points** requiring attention when fixing geysers:—

1. Adequate provision for carrying off entirely clear of the building the products of combustion from the gas burners.

2. Provision of a supply of gas sufficient to enable the maximum demands which may be made at any time upon the geyser to be met.

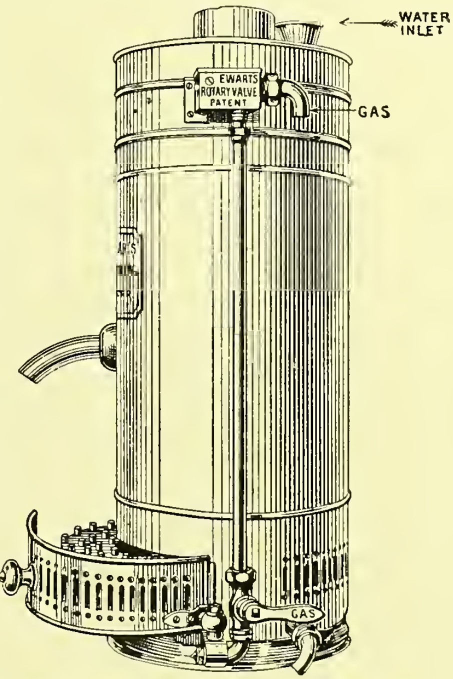


Fig. 425.—"Lightning" Geyser with Rotary Valve

Ventilation.—Care should be taken in fixing the flue or ventilating pipe to ensure an up current, and for the first 4 ft. the pipe should be vertical, any bends which are required being constructed above this, and to a large radius, to minimize friction. The fumes should always be turned into the open atmosphere, and should never be delivered into the spaces above false roofs. The top should be provided with a cowl of suitable dimensions and shape, which will not offer any resistance to the flow of the contaminated air from the apparatus, and which is so constructed as to prevent a down draught or reversal of the current of foul air. The material most commonly used for flue pipes is galvanized sheet iron, and the various lengths should be fitted into one another so that the sockets are pointing downwards. The advisability of taking the gaseous fumes from the geyser directly into the open air cannot be too strongly emphasized, as, owing to its not having been fully realized, fatalities have occurred, the occupants of rooms in which geysers were fixed being asphyxiated by the fumes from the burners. If a chimney flue is near, the ventilating pipe may be turned into it.

The gas supply to geysers is also most important. If the supply is inadequate, the apparatus will give disappointing results. It is advisable to provide a separate supply of gas from the meter to the geyser, as by this arrangement the requirements of the apparatus will not interfere with

the supply of gas for lighting purposes. The gas meter should be of ample capacity, as, if it is too small, the gas rushes through at an abnormal speed and causes the meter to register more than has actually been consumed. The gas pressure should never be less than $1\frac{1}{2}$ in. of water, the best working pressure for geysers being between $1\frac{1}{2}$ and $1\frac{3}{4}$ in. To ensure an even working pressure, and prevent extravagance in consumption, a gas governor should be fixed near the meter.

Water Supply.—There are two principal methods of supplying cold water to the fitting—"direct" and "indirect". In the first the water supply is connected directly to the geyser, and the tap controlling it constitutes part of the apparatus. This arrangement is objected to by many water companies, and the by-laws usually prohibit such a form of connection as will put the apparatus in direct communication with the public water supply. This objection cannot be urged where the supply to the geyser is taken from the storage tank.

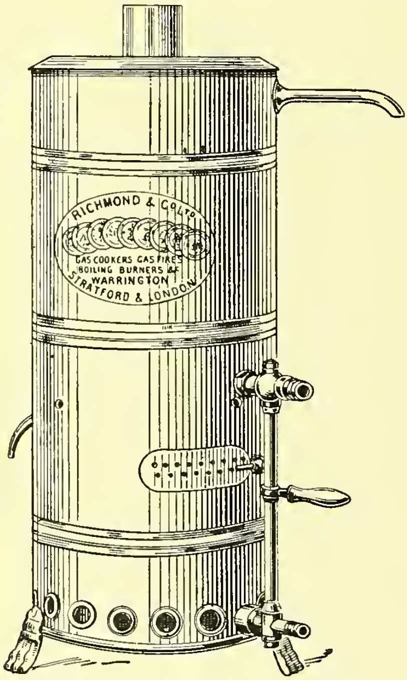


Fig. 426.—Geyser with Gas and Water Taps connected

In the second method the water from the main or storage cistern is supplied at the top of the geyser by a tap, which is fixed immediately above a funnel in the top of the geyser. This funnel leads the water to the chambers inside.

Gas and Water Valves.—In some forms of sealed geyser there is no provision for regulating automatically the flame of the burner to suit the varying demand for hot water, with the result that the interior chambers of the apparatus may be seriously damaged and a large quantity of gas wasted if the gas supply is not turned off when sufficient water has been obtained from the fitting. To prevent this, an arrangement known as a *rotary valve* may be attached to the fitting, through which the gas passes to the burner. When the supply of water is cut off or reduced, this valve automatically shuts off the gas, leaving only a small light, known as a pilot light, for relighting the main burners when the supply of water is again turned on. An example of a geyser fitted with a rotary valve is shown in fig. 425. The burner can be swung out for lighting, and the water enters at the top without a direct connection to the main. The rotary valve through which the gas passes is seen near the funnel at the top of the geyser, and a stop cock is provided near the burner to entirely close the gas supply.

Another type of valve for regulating the supply of gas and water is shown attached to the geyser in fig. 426. The gas and water taps

are connected by a spindle, to which the handle is attached, so that the gas and water are turned on or off together.

A third arrangement is shown attached to the heater in fig. 427, and is known as the "Vulcan" valve. The water and gas are entirely disconnected from each other, and no pollution of the water can take place from the escape of gas into the water pipe, and vice versa. Another arrangement sometimes adopted is shown in fig. 428, and consists of a locking device which only allows the gas to be turned on when the water-supply tap is opened. Many modern geysers are fitted with pilot lights which ignite the gas at the main burners when the tap is turned on.

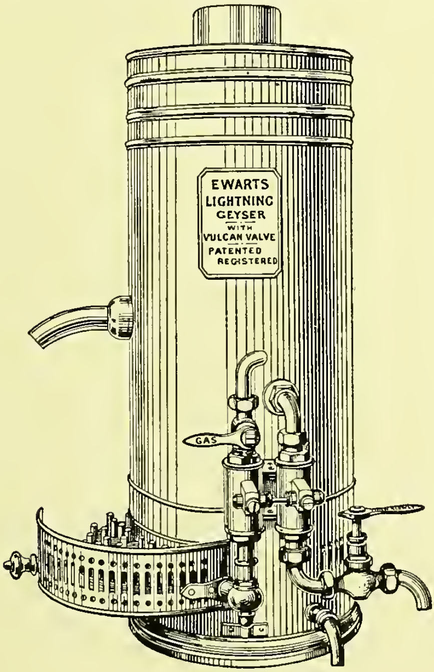


Fig. 427.—Geyser with Vulcan Valve

Fig. 428.—Geyser with Locking Arrangement

The "Ruud" Water Heater is fitted with a thermostatic valve, which can be adjusted to cut off the supply of gas automatically (with the exception of a pilot light), when the water has been raised to a certain degree of temperature. Thus, if the valve is adjusted to 160° F., the gas is automatically turned off when the temperature of the water rises to this point. When the temperature has fallen 20° or 25° F., either by the cooling down of the water or by cold water entering the heater to take the place of hot water drawn off, the thermostatic valve operates in the reverse direction and again turns the gas full on. The heater contains a series of coils of small copper tubing, and can be used for a run-through supply or in connection with a storage of hot water for supplying a number of fittings. In the latter case, the stored water is automatically maintained at a high but fluctuating temperature, the maximum being 20° or 25° F. above the minimum.

Geysers supplying more than one Fitting.—A modified type of the geyser illustrated in fig. 425 can be placed in a bathroom, and utilized for supplying both the bath and lavatory with hot water. A special connection is made at the back of the apparatus for supplying the lavatory, and when this is closed the bath is supplied through the spout. This spout is not provided with any valve or cock, and should always be left open and may discharge directly over the bath or indirectly through an india-rubber tube. In this apparatus the water supply is connected directly to the fittings. When fixing, care should be taken to ensure that the bottom of the apparatus is above the top of the lavatory. This type of geyser

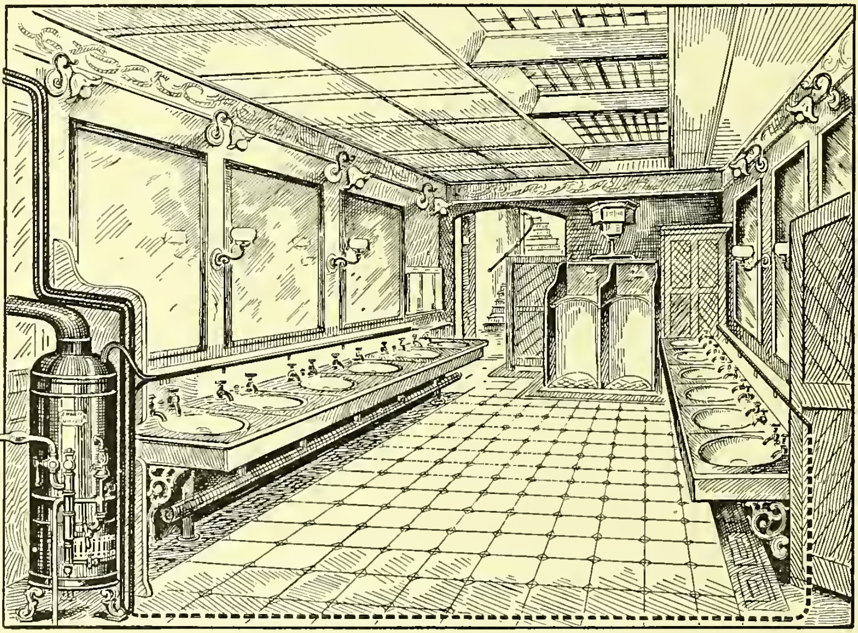


Fig. 429.—Geyser Supplying Ranges of Lavatories

belongs to the "sealed" class, as the products of combustion do not come in contact with the water.

Geysers are sometimes used for supplying hot water to ranges of lavatories in public conveniences, clubs, &c. In fixing these, the usual precautions should be observed with regard to the removal of the fumes and an adequate supply of gas. The geyser under such conditions would be fixed on the floor, and the supply to the lavatories taken from the top of the apparatus, the cold supply coming to the geyser either from the town's main direct or from an overhead cistern. Where the water container of the apparatus is entirely enclosed, with no escape for steam or accumulated pressure, it is advisable to provide a small safety valve, unless the geyser is fitted with a locking arrangement or with a valve such as the "rotary" or "Vulcan".

An arrangement for supplying hot water to two ranges of lavatories is

shown in fig. 429, and a hot supply to other fittings at a higher level is also provided for by the pipes leading from the top of the geyser.

The size of geysers depends upon the requirements of each individual case. A list of the principal sizes and the number of fittings they will supply, with the quantity of water heated in a given time, and other particulars, are given in the following table:—

Quantity of Water heated per minute.	Number of Fittings.	Internal Diameter of Gas Supply Pipe.	Internal Diameter of Water Supply Pipe.	Size.	
				Diameter.	Height.
Gal.		In.	In.	In.	In.
$1\frac{1}{2}$	1 Lavatory basin ...	$\frac{1}{2}$	$\frac{1}{2}$	9	29
2	2 Lavatory basins ...	$\frac{5}{8}$	$\frac{1}{2}$	$10\frac{1}{2}$	31
3	3 Lavatory basins or 1 Bath	$\frac{3}{4}$	$\frac{3}{4}$	$12\frac{1}{2}$	33
4	1 Lavatory basin and 1 Bath	1	$\frac{3}{4}$	14	38
6	1 Lavatory basin and 1 Bath and kitchen supply	$1\frac{1}{4}$	1	16	41
8	Full house supply ...	$1\frac{1}{2}$	1	$18\frac{1}{2}$	43
10	For large house ...	2	$1\frac{1}{4}$	20	48
16	For large house ...	2	$1\frac{1}{4}$	26	60

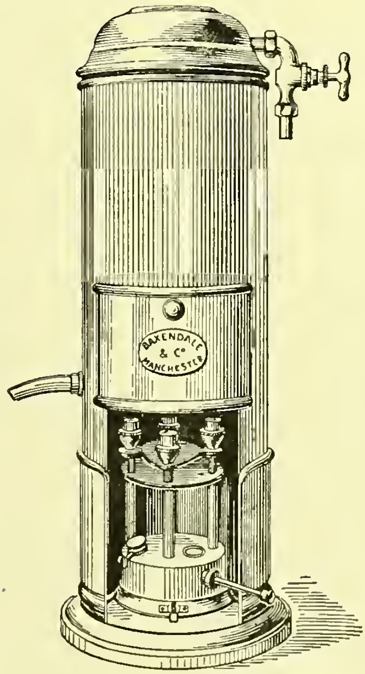


Fig. 430.—Geyser with Oil Fuel

In the above table the temperature of the water is supposed to be raised 40° F. above the temperature at which it enters the geyser. If boiling water is required, the quantity available per minute will be about from one-quarter to one-fifth the quantity raised 40° F.

The volume of gas required to heat a given quantity of water through a stated number of degrees will depend upon the burner and the arrangement of the heating chambers through which the water passes in the interior of the geyser. Generally speaking, 1 cu. ft. of ordinary coal gas will heat from 1 to $1\frac{1}{4}$ gal. of water 40° F. above its original temperature. On this basis a hot bath may be obtained, where the price of coal-gas is 3*s.* per 1000 cu. ft., for not more than 1*d.*

Geysers heated by the combustion of oil are sometimes used with advantage in isolated buildings where no gas supply is available. The oil generally used is paraffin, which is converted into a gas, by the peculiar construction of the burner, before it is consumed, no wick being

required. A small quantity of methylated spirit is used each time the burner is lighted, to heat it, and so vaporize the paraffin oil. A geyser of this description, which has proved satisfactory, is shown in fig. 430. It is of the "sealed" pattern, so that the water delivered from it may be used for drinking or cooking purposes.

Independent gas-heated boilers are sometimes used for supplementing the heat from the kitchen fire in a cylinder or cylinder-and-tank system of hot-water supply. The boiler may be on somewhat similar lines to that shown in fig. 429, but other kinds are also made, such as the storage type of the "Ruud" water heater. Primary flow and return pipes are fitted up between the boiler and the cylinder in one of the ways shown in fig. 379 and Plates XX and XXII. Gas-heated boilers of this kind are very convenient and easily attended to, but for constant use are not as economical as ordinary independent boilers with coal or coke fires. They are, however, well adapted for assisting the kitchen boiler during those hours of the day when hot water is in greatest demand.

SECTION VII

WARM AIR AND VENTILATION

BY

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SECTION VII
WARM AIR AND VENTILATION

CHAPTER I

THE PHYSIOLOGY OF VENTILATION AND HEATING

The practitioner who desires no more than to understand the methods employed in plenum ventilation and heating, will be content to gain the knowledge he requires without recourse to more theory than is absolutely necessary to a clear conception of the system. To facilitate the task of such a reader, the author has sifted and condensed most of the purely theoretical part of the work into the first two chapters.

Perhaps the first question that presents itself to the thoughtful reader is: **Why always couple ventilation with heating?** Are they not two distinct processes? The two are quite distinct in themselves, of course, but each is at the same time the cause and the effect of the other to such an extent that, though for the sake of convenience we may at times consider the process of heating or that of ventilation by itself, yet to deal with either alone as a science, whether theoretical or applied, would be impossible. The simplest example will suffice to show how far this is true. Light a fire in an ordinary room. Open all the doors and windows and there is a perceptible rush of air towards the fireplace, and we also note that the fire "gets up" more quickly. This expedient is so common in cases of flues that do not draw well that it would be hardly worthy of mention did it not show how heating and ventilation act and react, for in this case we recognize at once that in some way the fire causes the inrush of air, and in turn the air causes the fire to burn.

The primary purpose of heating and ventilation is the health and comfort of the human beings who, for the time, are within the building. In point of importance physiologically, ventilation takes precedence, as will be seen if we consider our essential bodily functions.

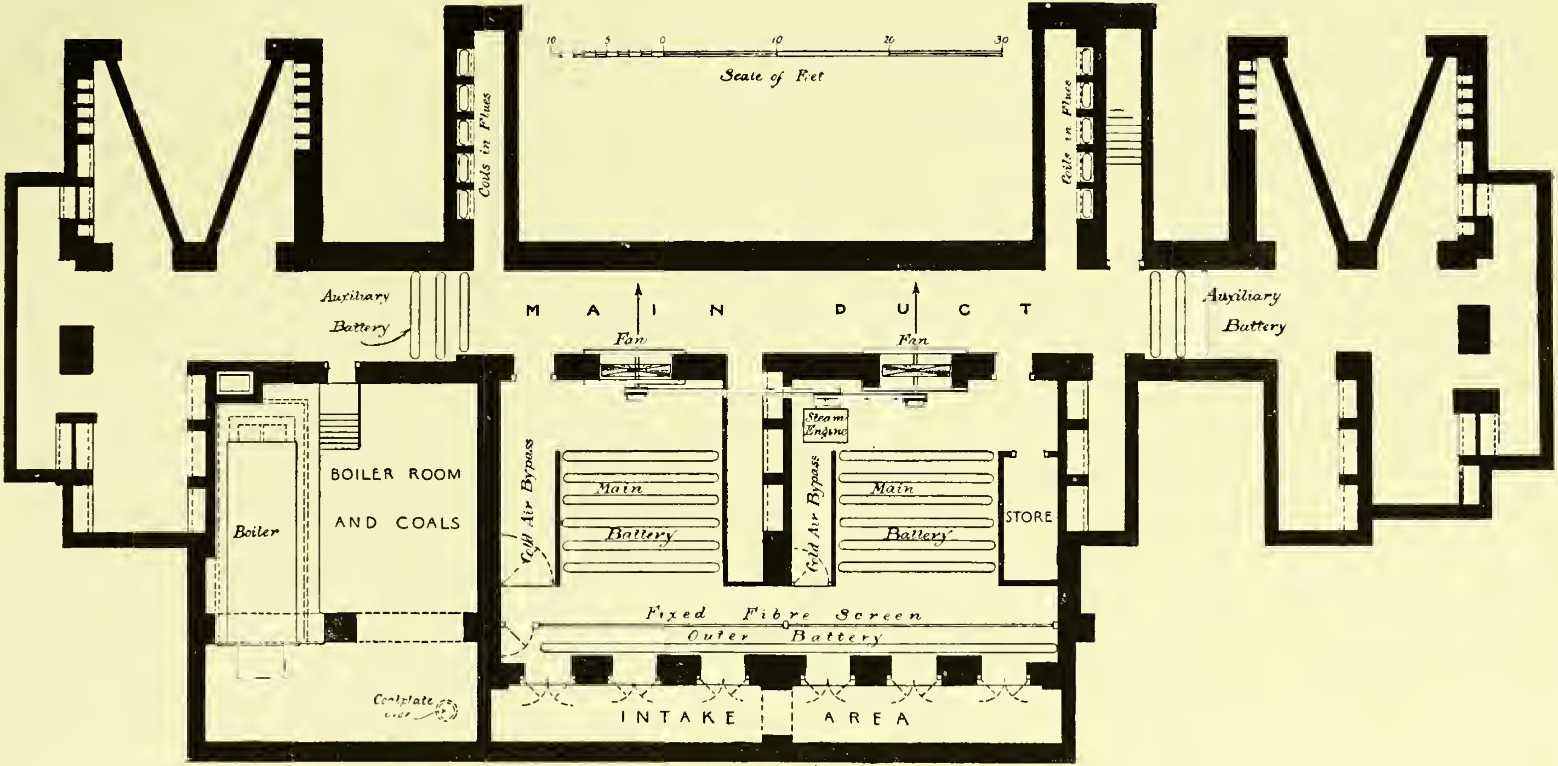
Any living animal may be regarded as a machine, more or less complex according to its position in the scale of organization. This machine is in constant motion, if not entirely, yet in certain parts. In fact, these movements may perhaps be said to constitute that which we call "life". A man may or may not be using his muscles in some active operation, but even in a passive condition his heart beats, his lungs perform the work of breathing,

and certain parts of his anatomical machinery continue to move as long as he lives. But with every movement of this complicated mechanism there is a corresponding waste of the tissues themselves. This wastage has to be got rid of, and new material must be substituted and the part repaired immediately; and, consequently, the greater the number of parts in motion the greater is the wear and tear and the greater the amount of material to be made good. This repairing operation is accomplished by the assimilation of food, which is taken in complex compositions and then reduced to simple constituents. The food is supplied at intervals as an engine is stoked; but if the machinery is to be kept running, the actual burning of the fuel must go on continuously. For this purpose a constant supply of oxygen is necessary.

The lungs constitute the most important agency between these internal requirements of the animal organism and the corresponding environments. They alternately inhale oxygen, which is the gas vital to our existence, and exhale part of the waste produce. The combined operation takes place (under ordinary conditions) from fifteen to twenty-one times per minute when the body is at rest. With increased muscular exertion the rate of respiration is increased to carry off the abnormal waste, and at the same time to take in sufficient oxygen to make good the loss. If the bodily condition as regards exertion is normal, and the external conditions are such as to reduce the supply of oxygen, the relation of supply and demand is similar to the case in which the muscular movement was abnormally great and the supply of oxygen was normal, with precisely the same effect upon the lungs. This is worthy of note as constituting a symptom of greatly impaired ventilation.

The operation of ridding the body of the waste is not confined to the lungs, and it is of some importance to the ventilationist to remember that **the skin** assists the lungs in this work. This is more particularly applicable to hospitals, where, in many cases, the lungs are partially incapacitated through disease, and, in consequence, the skin has to do more than its ordinary share in the performance of this function.

There is another aspect of this case of tissue change to be considered. Wherever and whenever it occurs there is a proportionate amount of **energy given off in the form of heat.** Whether the body be employed in violent muscular exercise, or whether it be in a passive condition, merely carrying out the vital processes, such as those of breathing, the movement of the heart, and the secretion of the digestive fluids, heat is generated according to the extent of activity and the consequent amount of change of tissue involved. In other words, a smith at work at his anvil, or even a student working with his brain, will generate more heat than a man asleep; and yet it is common knowledge that, assuming the person in question to be in a normal condition of health, his actual temperature will be the same. From which we can conclude that the man under great bodily exertion is expelling the heat he generates much more rapidly than the man who is exerting himself to a less degree, not merely as a hot body gives off more heat than a cooler one, but the surplus heat is actually expelled in order to preserve a normal temperature. Nature adopts a number of methods



A BASEMENT PLAN SHOWING MAIN AND AUXILIARY BATTERIES,

AND THE IMPELLED AIR ENTERING THE MAIN DUCT TRANSVERSELY

simultaneously in ridding the body of the surplus heat. Under ordinary circumstances a large amount is expelled with the expiration in breathing. The air, &c., taken into the lungs is generally considerably lower in temperature than the body, while what is expired is at blood heat or thereabouts, so that a large amount of heat is expended in this way. Heat is also used up, as it were, in converting the water in the system into aqueous vapour. Part of this is also driven out with the breath, and altogether the lungs may be said to get rid of about one-fifth of the heat. But most of it finds its way into the external world by conduction and radiation, and by perspiration.

It must be understood that **perspiration** takes place not only when beads of moisture appear on the skin, but continually, generally in the form of vapour, which is termed "insensible perspiration"; and it is only when the moisture is expelled more quickly than the surrounding atmosphere is capable of absorbing it, that visible sweating or "sensible perspiration" is set up. This function is regulated in accordance with the amount of surplus heat generated, for the evaporation of moisture (whether in perspiration or in any other form) is invariably attended by a reduction of temperature.

In like manner, the amount of heat given off by **conduction and radiation** is a variable quantity. As more heat is generated, the blood is driven by an automatic process in large quantities to the blood-vessels that run over the surface of the body, giving the skin the flushed appearance noticeable in one who complains of being hot. Under opposite conditions this process reverses its action. Should the vitality be lowered from any cause, and the amount of generated heat lessened, the quantity of blood sent to the surface is proportionately reduced, and under these conditions one experiences the discomfort of feeling cold.

From what has already been said, we know that the vitality is decreased with a decreased supply of oxygen, and practical experience will prove the theory that **defective ventilation** is conducive to the sensation of coldness, or, in other words, the temperature of a building that is badly ventilated must necessarily be kept higher than that of one in which an ample supply of oxygen is provided, to maintain the sense of being comfortably warm.

From the point of view of mechanics, the human body is a most wasteful piece of mechanism, for not only does it suffer constant loss of its own material in wear and tear, but it is estimated that, when producing work, it devotes about one-sixth part of the energy represented by the day's fuel, supplied in the shape of food, to the performance of the work, and wastes the remainder by transforming its energy into heat.

CHAPTER II

THE NATURAL PHYSICS OF VENTILATION AND HEATING

The physiological functions performed by the body in taking in oxygen and giving off the waste products, including the lost energy in the form of heat, may be said to be the internal arrangements for ventilation and heating. The science of ventilation and heating as applied to buildings may be defined as the provision of external environments which shall properly correspond with these natural bodily operations.

Pneumatics.—Before attempting to solve this problem it will be necessary to consider the nature of the various gases with which we have to deal, and we will first explain a few of the laws which apply equally to all gases.

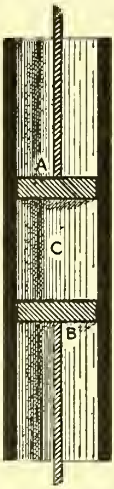


Fig. 431.—Diagram illustrating Air Pressure

Fig. 431 shows a section through a cylinder of an area of n in. It is fitted with two light pistons, A and B, the weight of which may be neglected. The space C between them contains nothing but the air (or other gas) under ordinary conditions. Now, if a weight of W lb. per square inch of section—that is, Wn lb. in all—be placed on A, and at the same time an upward force of Wn lb. be applied to B, the result would be that the pistons would approach each other, and the chamber C be consequently reduced. The pistons, however, would not meet, but would rest with a space between them, since the gas in C is unable to escape. If a pressure gauge were fixed (either to one of the pistons or to any point in the side of the cylinder between the pistons) to show the pressure of gas in the chamber C, we should find the pressure registered at W lb. per square inch. If the force at B be increased, both pistons will move up, and with an increased weight at A the reverse movement would take place; but there will always remain a space C between the two. Remove both forces, and the distance between the pistons will be the same as at first.

We have now exemplified **several well-known laws.** It has been noticed that the force has been transmitted from one piston to the other, though they have not come into contact, and the pressure gauge has shown that a similar force has been exerted at all points in all directions. From this we may conclude that *if a force be applied to a body of gas, a similar force (per unit of force per unit of area) is transmitted to all points and in all directions.*

We noticed, too, that the space C was reduced when the forces were applied, so that *gas diminishes in volume under pressure*; and lastly, when we released the pistons the air chamber assumed its former dimension. *Gas, therefore, is a perfectly elastic fluid.* In this manner we can prove what is known as "Boyle's Law", which states that, *assuming the*

temperature of a gas to be constant, the pressure or elastic force which it exerts will vary inversely as the volume it occupies.

Let the weight Wn lb. and the upward force Wn lb. be applied as before, and the air in the chamber C be heated. The air now seems to resist the pressure to a greater extent, and the pistons are driven farther apart. Cooled to its former temperature, the pistons return again to their original positions; cooled still further, they approach each other.

Thus we might illustrate the well-known fact that *the resistance of the air is increased or decreased as the temperature is raised or lowered*; or to express it more definitely in the terms of Gay-Lussac's law, *the pressure of gas being maintained constant, it will expand $\frac{1}{273}$ of its volume for every degree (Centigrade) rise of its temperature, or, conversely, if its volume be constant, the pressure will increase $\frac{1}{273}$ under the same conditions.*

Now suppose the first process to be reversed. Let a small weight Wn (something appreciably less than 15 lb. per inch of area) be applied to the lower piston B, and let a greater upward force act upon A. Then the two pistons will move some distance farther apart, after which the upward force of Wn will appear to draw the weight up.

Let us examine these two phenomena. In the first place the air chamber has increased in size. If the pressure gauge be again referred to, we find some pressure registered (about 15 − W lb. per square inch). We have therefore discovered the natural tendency of gas to expand, when relieved of pressure, in such a manner that, no matter how small the quantity of gas, and no matter how large the limits in which it is confined, it will fill the whole space and still exert some pressure; in fact, the particles seem to repel each other, in opposition to the general law that every body attracts every other body.

And yet this seems to be contradicted by the second phenomenon, in which, after a certain amount of extension, the confined air or gas appears to resist further enlargement, as if there were some cohesion of its particles, rendering it possible to transmit force from the piston A to the piston B, by which the former draws the latter up after it. It is upon this fallacy that the common idea of *suction* is founded, which is the erroneous conception of the possibility of drawing air by the application of a tensile stress.

Referring once more to the cylinder and pistons—if the value of W were increased so as to exceed 15 lb., we should find that no matter what upward force were applied to A, it would no longer draw or suck the lower piston up. Why is this? So far we have neglected the atmospheric pressure which is acting on all parts of the apparatus with a force of about 15 lb. per square inch. Without any other forces being applied, we know that this pressure is acting always on the pistons, tending to press them together; but they are kept apart by the intervening gas, which, if air at the same temperature as the external atmosphere, will assume such dimensions as will render it of the same density. The whole is then in equilibrium,—that is, each piston has a pressure of 15 lb. per sq. in. pressing it inwards, and an equal and opposite pressure pressing it outwards. When the small weight was applied to B, and the corresponding upward force applied to A, they parted for some distance, and then the weight appeared

to be drawn up by the excess of the force at A over the weight on B. Had the upward force been equal to the weight, of course, after extension of the chamber C had taken place, the whole would have remained at rest. Let us now consider the piston A to be fixed in that position and consider the forces which hold B in equilibrium. We have the external atmospheric pressure of $15 \times n$ lb. acting upwards. Opposed to this there are the weight $W n$ and also the pressure of the air in the chamber C, which now, being rarefied, exerts a pressure less than 15 lb. From these we get the equation—

$$
\begin{aligned}
Wn + \text{the pressure of the air in C} &= 15n. \\
\therefore \text{the total pressure of air in C} &= 15n - Wn. \\
&= (15 - W) \text{ lb. per square inch,}
\end{aligned}
$$

as was registered by the pressure gauge.

From this it will be seen that the lower piston was not drawn or sucked up by any force transmitted from the upper one; but that by the increase of the chamber C, the air, with its natural tendency, filled the enlarged space, and consequently became rarefied and reduced its pressure till B was held in equilibrium. The external atmospheric pressure acting upwards on B did the work of raising the weight, as is evidenced by the last phenomenon, where we found that when W exceeded 15 lb. the force on the upper piston would no longer sustain the weight, but the piston B fell indefinitely irrespective of the upper one. This happens simply because the air in C refuses to transmit a tensile stress.

Imagine for a moment that it was otherwise, the lower piston being held in equilibrium as before. We have already ascertained from the previous equation that the downward pressure of air in the chamber C on the piston B = (15 − W) lb. per square inch. If W exceed 15, then this pressure is a *minus* quantity—that is, a tensile stress upwards, which by experiment we have found the air fails to supply. Therefore we can conclude that although air will resist compression it offers no resistance to tension, and consequently such a force cannot be transmitted by it. The importance of this fact will be seen later.

It has already been stated that the vital element upon which we may be said to live is **oxygen.** But to inhale this gas in its pure state would be to stimulate the system and to increase the vitality to such an extent that the human machinery would very soon break down through the abnormal speed of its working, and life would be a short one and a merry one indeed, —particularly the former. On the other hand, an insufficient supply of oxygen would tend to "slow down" the mechanism, and the same final result would be arrived at by the reverse process.

Under natural conditions (which is here another phrase for "perfect ventilation") oxygen is supplied to the lungs in the diluted form of air. **Pure** air is composed of a mechanical mixture of 21 per cent of oxygen to 79 per cent of nitrogen, or roughly $\frac{1}{5}$ oxygen to $\frac{4}{5}$ nitrogen. This is what a chemist would call *pure air*; but it is doubtful whether such an atmosphere could be discovered outside of the laboratory, and much as we hear of the boon of "pure air", it would be extremely unpleasant to breathe.

The air as it exists around us is more or less charged with **moisture in the form of vapour.** The atmosphere possesses the power of taking up moisture to a certain degree whenever it can be found. The effect of this is to be seen whenever anything is hung out to dry or air. Three conditions augment its powers of absorption. These are well known to the laundress. A high temperature of the atmosphere causes the clothes to dry quickly, and atmospheric movement, or wind, tends towards the same effect. Moreover, a dry air carries off moisture more rapidly than a damp air. In fact, the air is only capable of taking up a certain amount of moisture according to its temperature, and its power of absorption diminishes in proportion to the amount of aqueous vapour it already contains, until it reaches the point of saturation, when the drying power of the air ceases altogether.[1] Now, were the air chemically dry, the natural moisture of the throat and lungs would be caught up far too rapidly, and we should experience the unpleasant sensations which we do when shut up in a badly ventilated room where the temperature, and consequently the drying properties of the air, have been raised and no corresponding surcharge of vapour provided for. On the other hand, when the condition of the atmosphere approaches saturation, the air loses its power of absorption to such an extent that the function of perspiration is retarded. This necessity for properly moistened air must be remembered in considering any scheme of ventilation and heating, and, if possible, means should be provided whereby the degree of humidity can be regulated.

It should be noted here that the atmosphere contains a percentage of **carbon dioxide** (of which further mention will be made shortly). Though essential to vegetable life, it is by no means beneficial to animal existence, so far as science has yet discovered. However, it seldom exists in a greater proportion under natural conditions than ·04 per cent, which is insufficient to prove deleterious.

The lungs take in about 20 cu. in. of air at each inspiration. But what is given off in the exhalation is, as we know, of an entirely different nature, and is what we hear so much about in reference to ventilation under the enigmatical appellation "vitiated air". As far as the nitrogen inhaled is concerned, its only office is that of a diluent, and it is returned to the outer air with the vitiated air as nitrogen still, and even with a small quantity of nitrogen added. It is with the remaining portion of the exhalation that the subject of ventilation has more particularly to deal.

A very simple experiment will reveal something of its composition. Put some lime water (which can be obtained from any chemist) in a tumbler or other suitable vessel, and blow into it through a tube; it will very quickly lose its watery appearance and become cloudy and white. If the operation is continued, a white deposit will be found in the vessel, which will be a combination of carbonic acid and some of the lime that was in solution in the lime water, and the precipitate is therefore called "carbonate

[1] It is this fact which points the reason for a moving atmosphere possessing high powers of absorption, for as the air takes up the moisture at a certain place, and itself becomes more highly charged, it moves on, and its place is taken by drier air. So we fan ourselves to assist in the removal of heat from the body which is given off by perspiration.

of lime", or, to use a plainer word, "chalk". But the whole of the gas which has been exhaled has not been carbonic acid, though one hears so much (in connection with ventilation) of carbonic acid or, as it is more often called by modern scientists, carbon dioxide, that it would appear as if exhaled or vitiated air were made up entirely of this gas. As we have already noted, the exhaled air is mostly nitrogen, and as a matter of fact not more than from $\frac{1}{30}$ to $\frac{1}{25}$ of the expired waste is in the form of carbon dioxide.[1] This gas is formed by the union of the carbon (gleaned from the carbonaceous matter of the animal wastage) and oxygen (taken from the air), the two elements being in the proportion (by weight) of 12 of carbon to 32 of oxygen (CO_2).

The best manner of noting the **nature of carbon dioxide** is by obtaining some of the gas in question in an undiluted state. This can easily be done by a process which is somewhat of a reversal of our previous experiment,—that is, by driving the CO_2 out of a piece of chalk. Some simple apparatus will be necessary, but the experiment is well worth the time and trouble involved. The apparatus required consists of a glass tube, bent twice at a right angle, with one arm longer than the other (as shown in fig. 432), and also two wide-necked bottles, one of which must have a cork to fit. The first piece of apparatus can be obtained very cheaply from any shop where chemical appliances are sold, and the latter can be obtained still more cheaply from the lumber cellar. Insert the short arm of the tube tightly through the cork. Drop a piece of ordinary chalk into one of the bottles, and add some hydrochloric acid, mixed with an equal quantity of water. Cork the bottle, and drop the long arm of the tube into the empty bottle; it is not necessary for this bottle to be corked. An effervescence will be noticed in the bottle containing the chalk and acid. What is really happening is that the acid is releasing the carbon dioxide from the chalk. The gas will soon fill the bottle, and, having no other means of escape, it will rise and pass through the tube and be deposited in the other bottle. In a very little while a lighted taper put into the uncorked bottle will be extinguished as though it had been plunged into water. Relight the taper and put the lighted end into the bottle once more, and by this time it will be found that it is not necessary to put the taper down so deeply into the bottle before the flame is extinguished. It is as though some invisible water were rising in the jar until it is filled to overflowing, and a lighted taper is extinguished immediately it enters the neck of the bottle.

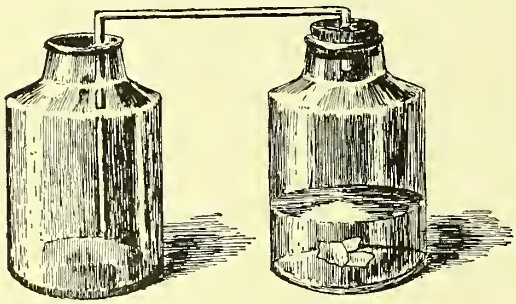


Fig. 432.—Apparatus for obtaining CO_2 from Chalk

[1] This amount varies according to the vitality of the person. During sleep, for instance, it is estimated that the carbon dioxide given off is 25 per cent less than under ordinary conditions of daily life.

We have now a bottle of carbon dioxide. Already we have noted its nature in one respect—it will not support combustion.[1] Neither will it support life, for if a mouse or a frog or any other animal be dropped into the jar, it will be dead in a very short time.

Now, if the bottle be canted over above a lighted candle, as though we were pouring water over the flame, the light will be extinguished. Or if we turn it over above an empty bottle, or, more correctly, a bottle containing air only, and then the light test be applied to the new bottle, the result will be the same. So that it is possible to pour out CO_2 or to drop it from one bottle into another. When it is remembered that the atmosphere surrounds us on every hand, and at first filled the bottle which now contains the carbonic acid gas, we have illustrated two important facts. One is that carbon dioxide is heavier than air and sinks beneath it, as it did into the last bottle, lifting the air above it; and the second is the general law of gravity, which causes all heavy gases to sink when thrown into a lighter gas, just as a heavy liquid—mercury, for example—will sink when dropped into water, causing the water to float above it.

The Law of Gaseous Diffusion.—The truth of the general law of gravity acting on gases is not so much of the nature of a self-apparent axiom as at first it may seem. Take a fresh bottle of the CO_2 (the necessity of a fresh bottle will be evident presently). Take another bottle with a neck of corresponding size and containing nothing but air, invert it over the one containing the carbon dioxide, and seal the two necks together so that no air can get either into or out of the bottles. After a while, if they be parted, and the top bottle immediately turned into an upright position on its bottom, we shall find that an important change has taken place in the nature of its contents. By applying the simple test of inserting a light, or pouring a quantity of lime water into the bottle, the existence of carbonic acid will be evident *in both.* That is to say, some of the heavier gas, which seemed at first as if it would remain like water in the lower bottle for all time unless it were disturbed, has so far defied the force of gravity as to rise into the upper bottle, while some of the air that occupied that vessel must in consequence have fallen into the lower. In the course of time the two gases, without any artificial agitation, have mixed, despite the difference in their respective weights. The same effect would have resulted from any other two or more gases (provided, of course, they were not such as would explode on contact or produce some other phenomenon). In short, the law is a general one, that when two or more gases are brought into contact, though at first they seem to remain in separation, in time they will mingle, no matter what the difference in weight may be. This law is known as the "Law of Gaseous Diffusion"—an important canon in the science of heating and ventilation, though, unfortunately, too often forgotten.

Many experts regard carbonic acid gas as not poisonous in itself, but merely harmful on account of the manner in which it dilutes the atmos-

[1] This is really the test applied when a light is lowered into a newly-opened well or cess-pit which has been closed for some length of time. If the light be extinguished, it points to the existence of carbon dioxide.

phere, taking the place of the oxygen and making the air poor in that respect. This scarcely seems to be a correct valuation to put on the physiological effects of breathing CO_2, for where the oxygen is reduced to 17 per cent of the air, and carbonic acid substituted, life is not supportable; but if instead of carbonic acid we substituted nitrogen, which is known to be perfectly inert, the quantity of oxygen might be reduced considerably below 17 per cent, and the atmosphere still be breathable.

But however we may regard the deleterious effect of the presence of a high percentage of CO_2 in the air, there is no doubt that some of the other constituents of our bodily waste demand far more suspicious attention. These are various and uncertain, and impossible to measure accurately. Though in bulk comparatively small, the most objectionable are the particles of decomposed matter, which represent a part of the excretion due to the continual disintegration going on in the animal system. This effete matter is passed off from the skin as well as from the lungs, and is often accompanied by fetid vapours. Apart from their own objectionable nature, these particles may be said to be the native element of germ life. But owing to the fugitive nature of the more objectionable matters, carbon dioxide, the characteristics of which are more stable, is taken by ventilation experts as a standard by which to measure the amount of air vitiated, it always being found in direct proportion to the other excretions.

As the gases given off from the body emanate at a temperature almost equal to that of the body (about 99·5° F.), which is under ordinary circumstances higher than that of the surrounding atmosphere, they exist in a somewhat rarefied form, owing to their expansion under the influence of heat. The buoyancy of the vitiated air naturally increases with its bulk, and although, loaded as it is with carbon dioxide, it would, under a similar temperature (or even only approximately similar), be considerably heavier than the atmosphere, yet the influence of the heat it contains more than compensates for its naturally excessive weight, and causes it to rise on leaving the body. This upward movement depends on the height of the temperature of the vitiated air above that of the adjacent atmosphere; consequently the colder the surrounding air the more lively will be this upward movement. But immediately the excreted gases leave the body they begin to cool rapidly, and in no case will they, of their own buoyancy, ascend to any great height above the head. And even though they rise more briskly in a cold atmosphere, they also cool the more quickly, and begin to fall long before their temperature is reduced to that of the air.[1]

This rising of the bodily emanations is often greatly exaggerated. It is no uncommon thing to find the upper part of a hall, or the open roof of a lofty church, regarded as a sort of inverted tank filled with the vitiated air that has arisen from the congregation below. That the case of the upper part of a room or building being filled with hot and perhaps vitiated air often exists is a matter of common knowledge. One need but occupy a seat in the gallery of a badly ventilated theatre that has been illuminated

[1] Of course, in such an extraordinary case as where the temperature of the atmosphere equalled, or nearly equalled, that of the body, the vitiated air would fall at once.

for a time by means of the burning of gas; whether there be anyone else in the theatre or not, the probability is that the air near the ceiling will soon become extremely unpleasant, on account both of its temperature and also of its constitution.[1] But this has nothing whatever to do with the bodily emanations from any persons on the floor, for the density of newly vitiated air is not less than that of pure air at from 78° F. to 81° F. Its buoyancy, therefore, can never be such as to give truth to the idea that the expired air lodges close to the ceiling, with the accompanying fallacy that the higher a room the better are its sanitary conditions.

Dr. George Reid, M.D., in his *Practical Sanitation,* places this fact in a very strong light. "The height of a room", he says, "is an important consideration in a ventilation enquiry. The respiratory impurities tend to accumulate about the occupants of the room, and beyond a certain point *loftiness will not take the place of floor space.* The air of a space enclosed by high walls, but uncovered by a roof, would soon become very foul if the space were overcrowded. There is no objection to a lofty room, but it must be remembered, in estimating the capacity in a ventilation sense, that a height of 12 to 13 ft. only should be considered, as this may be taken to be the maximum useful height of a room."

But though the foul air sometimes found in the upper portion of the room is not the result of respiration and perspiration, yet it exists nevertheless, and must therefore be dealt with, so that in this way we are faced by another element of the problem. In most of the essential particulars **the vitiation of the air by combustion** (as in the case of illumination by gas, for instance) is similar to the chemical changes which take place in consequence of the presence of human beings. Oxygen is consumed and carbon dioxide and water vapour substituted. There is, of course, no decomposed animal matter given off, but there is the suspicion of the possible presence of carbon monoxide (CO) and other noxious gases. In short, the products of combustion are much of the same nature as those of the analogous animal functions, and in both cases it is the business of ventilation to get rid of them as quickly as possible. A simple gas jet will consume as much oxygen as from three to five persons. But though so similar chemically, there is a great and vital difference from the point of view of the ventilationist in the wastages from these two sources. Whilst those emanating from the human body are merely warmed a little above a normal air temperature, and soon find their way to the floor, the products of combustion are heated to a very high degree, and consequently rise rapidly, and, in the absence of any exit, remain near the ceiling for a considerable time, until they at last cool and descend, or become diffused through the atmosphere in

[1] Even in this instance, when the audience is present, it does not necessarily follow that the upper part of the atmosphere is worse than the lower, as is shown in the following case, which is quoted by Mr. W. P. Buchan, R.P., who, referring to a letter from Mr. John Foggie, F.C.S., of University College, Dundee, speaks of that gentleman's "finding the state of the air in Her Majesty's Theatre, Dundee, to be, at half-time, in the gallery 32 volumes (of carbon dioxide) per 10,000 (of air), and in the pit over 50 volumes. The theatre was crowded." Mr. Buchan, to whose theories this letter would seem somewhat adverse, says with commendable straightforwardness: "He (Mr. Foggie) refers to this as an instance of the exhaled CO_2 not rising; but low roof of pit and currents of air had to do with this". The present writer suggests that the theatre being crowded had more to do with it, for probably there were more people on the ground floor than in the gallery.

Fig. 433.—Masses and Currents of Vitiated Air

the room, or both. Fig. 433 will perhaps convey the idea of the behaviour of the two classes of vitiated air.[1]

The principal factor tending in any way to affect these natural dispositions of the vitiated air is the modification of the temperature of the whole or portions of the air, for its positions are due to its specific gravity in relation to the general atmosphere, the weight of which, of course, varies with its temperature.

Heat may be transmitted in three ways: by conduction, by convection, and by radiation. By *conduction*, calorific energy is transmitted by direct contact. This plays but a small part in the heating of buildings. *Convection*, which is, to a certain extent, analogous to conduction in that the heat is conducted by the moving particles of a fluid such as water or air, is in some methods of heating a most important factor. The atmosphere presents a very apt medium for the generally uniform distribution of heat owing to the rapidity of its expansion by a rise of its temperature, when, its density being affected, equilibrium is destroyed and the heated particles are immediately set in motion. *Radiation* is the term used to denote the transmission

[1] The illustration must be taken as showing the general behaviour of the gases in question, and not with the idea of mathematical exactitude. The gases are invisible, and, from the results of change of temperature and of diffusion, their course cannot be traced with absolute accuracy, but must be computed by theories, the correctness of which practice alone can prove.

of heat irrespective of any intervening substance save the all-pervading ether. It is in this way that the heat of the sun travels through space to the earth, and in the same manner the heat from an open fire finds its way to the neighbouring bodies. In a room the atmosphere is naturally set in motion at the same time, and we get the transmission by convection also; but the action of a fire in a room is dependent principally on radiation, while in the case of steam or hot-water pipes and radiators, or as in the system of heating by propulsion, the distribution of heat is wholly by convection.

Fig. 434 illustrates an example of the **aerial motion caused by heating** by convection. R is a radiator standing on the floor against the wall of a closed room. The air surrounding the radiator is instantly heated. and by its newly acquired buoyancy rises rapidly to the ceiling. It cools in its passage by communicating its heat to the immediately adjoining air, and also to some extent by diffusing with it. In consequence it loses its buoyancy very gradually, and its motion becomes slower. It is still forced on its way by the succeeding body of air, which, continually rising, adds to the accumulation of heated atmosphere. So the air first warmed is pushed along the ceiling in all directions, and, becoming cooler, is pressed down from its lofty position to make room for the continual fresh supplies of warmer air. Thus the stream goes on—cooling, increasing in quantity, and decreasing in velocity. Turning again to the radiator, we find the air driven in from all quarters to fill the space, as it were, caused by the sudden uprising of the column of heated air. This illustrates the general motion of air of varying temperature, and may be regarded as a circulating system.

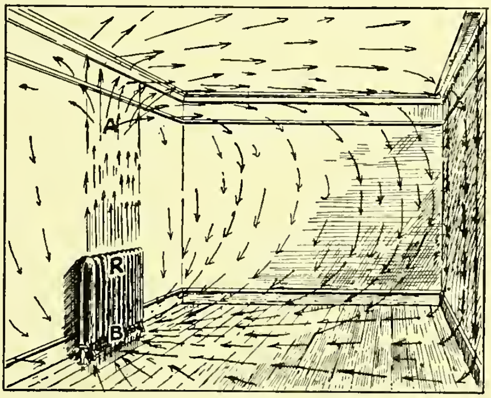


Fig. 434.—Air Currents in Heating by Convection

It was premised that the room was *closed*, but it is easily conceivable that the circulation may be modified by external influences. To put this in another way, the circle might be tapped at any two points (in the same way as an electric current), and, if air be introduced at a certain velocity, direction, volume, and temperature at one point, and drawn off at another, it is plain that, as the necessary conditions of part of the circulation are thus artificially supplied, the remainder of the circulation would behave in the same manner as before described. If, for instance, a current of air were introduced at A in precisely the same condition as that which is illustrated in the diagram, and the air were drawn off or extracted at B, the general circulating effect of the atmosphere would be exactly similar, except that, instead of the same air rotating over and over again, by tapping the circulation in this way we change the air as it circulates

As will be seen later, the modern principle of ventilation and heating by propulsion is very largely founded on this fact.

CHAPTER III

THE NATURAL METHOD AND THE MECHANICAL

The ventilation of buildings is attempted in many different ways, the degrees of success depending not only on the method, but also on the suitability of the system to the particular building, and on the manner in which the system is applied. Some systems include heating as an essential part, whilst others provide for change of air only, and neglect the question of heating and its effect on ventilation. Many are so far incomplete as to provide for only the admittance or the expulsion of air. Such schemes as the last, though unfortunately too common, can scarcely be termed ventilation at all.

In one respect all systems of ventilation are similar. Ventilation being a well-ordered movement of the atmosphere, force in some shape or form is required, and since, as we have already seen, air will receive force in one way only, by compression, every system of ventilation must be literally a propulsion system—that is, fresh air must be driven into the building and the vitiated air driven out by the new supply.[1] The "vacuum" or "exhaust" system is but another form of propulsion, in which the air existing in the apartment is allowed to expand by relieving it of the atmospheric pressure at one or more points, and so reducing its own pressure on the walls and other confines. Then the excess of atmospheric pressure outside is ready to drive in the air through any aperture provided for the purpose, or left by accident.

Two distinct methods of ventilation are in common use, namely, *natural ventilation*, in which advantage is taken of the forces supplied by nature in the form of atmospheric momentum or wind, and *mechanical ventilation*, in which the air is propelled into the building by mechanical means. The former method is often assisted by some contrivance of a mechanical nature, which is operated by the force of the wind in such a manner as to reduce the atmospheric pressure where it is placed, and so cause a rarefaction of the internal air.[2]

Natural ventilation is the simpler and cheaper, as it is also the older method of air change. The wind supplies a motive force ready to hand, and it is reasonable in most instances to take advantage of it for this purpose, as we do for the propulsion of ships and boats and the working

[1] It is possible for a certain amount of air-change by dilution to take place through one opening only, in virtue of the gradual diffusion of the external atmosphere with the internal, but such a process is so slow that it cannot be regarded seriously.

[2] Doubtless some of these appliances are useful, but many cannot be relied upon to perform all that is claimed for them, and often those that would otherwise do some good are injudiciously placed. The writer constantly observes two of these "extracts" of the Archimedean type, which are placed on a building just outside his office window. Their position is such that they as often revolve one way as the other.

of mills; but just as in these latter instances more certain and scientific methods of propulsion have risen and are still rising in favour, so it is with ventilation. Our smaller buildings, and many of our larger ones, where cost is of first importance, must still be ventilated and heated in the old-fashioned way, and will continue to be so, at least till some better method, compatible with their circumstances, is devised. But in the case of large buildings where a little extra cost on the initial outlay and on the subsequent maintenance is not an insuperable obstacle, the old mode is gradually giving place to the new.

The great defect of wind pressure as a motive force—whether applied to the requirements of ventilation, navigation, or any other purpose—is its inconstancy. It varies both in quantity and direction. This changeability is disastrous in its effects on ventilation, and the defects are increased by the general method of heating employed with natural ventilation.

Take the case of a room provided with a suitable opening, such as a well-placed window, for the admittance of fresh air, and assume that all the circumstances are favourable to ventilation: that means of exit are provided for the foul air, such as flues or another window; that the building is situated in the country, where the air is clean and well-charged with oxygen, to the practical exclusion of carbon dioxide and other deleterious gases; that the external atmosphere is at a desirable temperature, so that no artificial heating is necessary; and that the natural temperature of the room is not appreciably higher or lower than that of the surrounding air. Assuming all this, and, furthermore, that a gentle breeze is blowing towards the window in a line about normal to the plane of the opening, then, under these conditions, we have excellent ventilation supplied by natural power. But should one of the foregoing conditions not be satisfied, then the ventilation will become inconvenient, unsatisfactory, or non-existent. If, instead of driving directly into the window, the direction of the pressure is oblique, less air will pass into the building, unless this can be rectified by the opening of a wider inlet area. But if the wind does not impinge on the wall containing the window—unless there is another inlet opening more suitably placed—ventilation ceases to exist in any measurable degree. The same result would occur in the event of a calm, and it also follows as a corollary that the amount of air change is reduced in proportion to the wind. If, on the other hand, the air enters the room at a high velocity, a breeze is created which may become inconvenient and even distressing, not only from its contact with the person, but from the motion imparted to all the lightest articles in the room. The quantity of air admitted may be regulated, of course, by the partial closing of the window, but the speed of its entry remains the same.

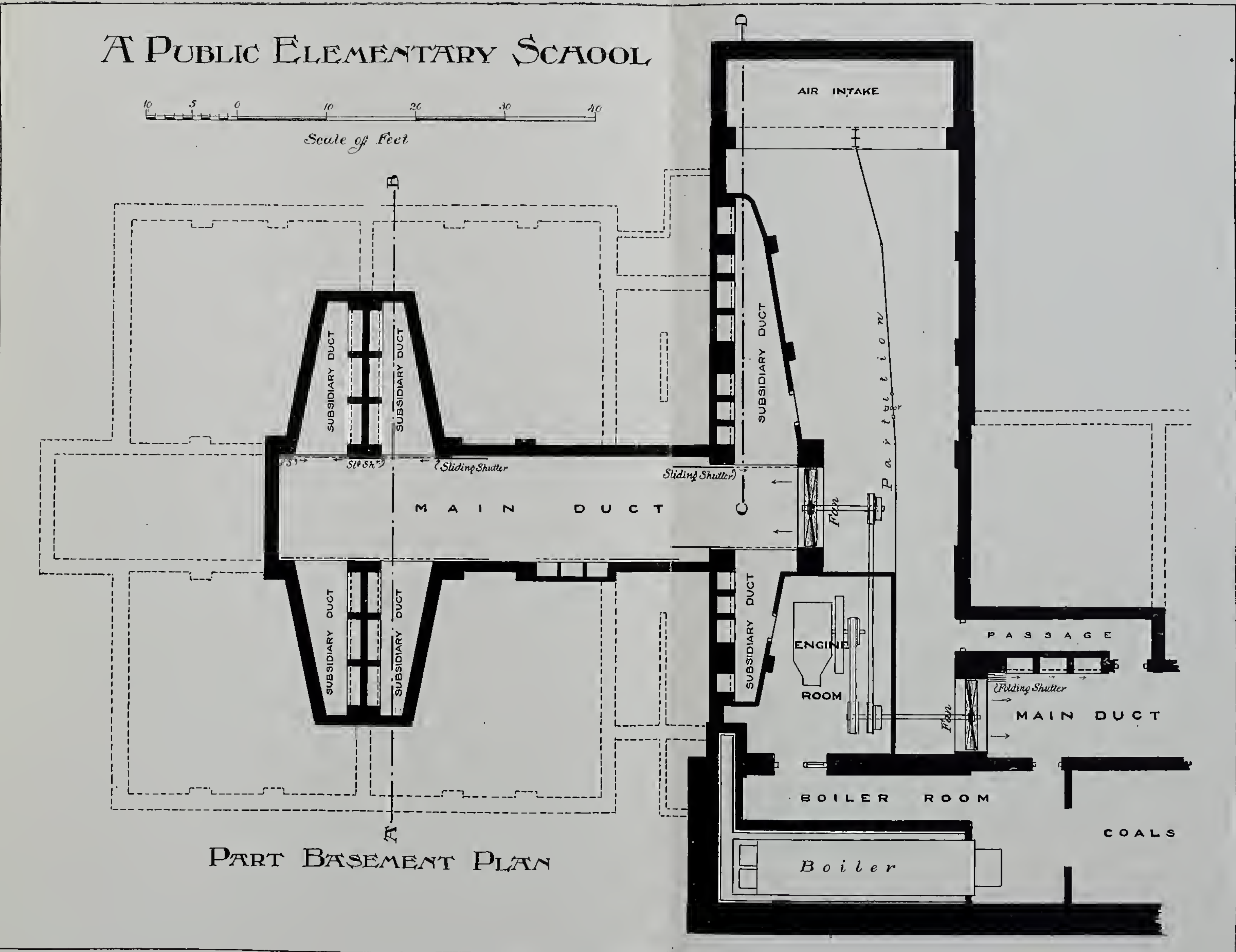
In winter a new set of difficulties is to be met with, particularly if the room is heated, for in that case the air admitted is considerably cooler than that already in the room. Here we have that bane of natural ventilation, a draught—and, worst of all, a cold draught. This is not only detrimental to health, but also unpleasant; and the latter consideration is often of far greater weight than the former.

If the apartment is heated by any means by which the air from the room is suddenly expanded and driven up a flue, the possibility of ventilation is greatly enhanced thereby, as the atmosphere in the room, becoming slightly rarefied, offers less resistance to the incoming air, and even in the absence of wind pressure exhaust ventilation takes place, and a plentiful supply of air will, if permitted, stream in, owing to the excess of atmospheric pressure from without; but it enters in the form of a cold draught. If the inlet is low, such as the aperture formed by the raising of the lower sash of the window, the draught blows directly on the occupants, pushing its way along the line of least resistance towards the stove or fireplace. If, on the other hand, air is admitted through the upper part of the window or through a fanlight, even though an upward tendency is given by the use of a hopper or some such device, its weight compared with the warmed and rarefied atmosphere of the room is such as to send it down almost immediately on the heads of the occupants like a cold shower. The usual procedure in that case is a matter of common observation. All doors and windows are promptly closed, sand bags, &c., are laid over the meeting rails if there should be any opening between them, and all crevices in defective joinery are pasted up, and everything made "cosy and snug" (and, it may be added, insanitary) for the winter.

Apart from the effect of draughts, the inequality of the temperature is further added to if the room is heated by combustion, in which case most of the heat is communicated by radiation. The effect, of course, is that near the fire it is hot, while the more remote parts of the room remain cold. To state this fact accurately, the intensity of heat by radiation varies inversely as the square of the distance. If hot-water or steam pipes and coils are used for heating, less of the heat is communicated by radiation and more by convection. This is an advantage, in so far as it distributes the warmth more equally, but it has the disadvantage of heating the air without driving any of it out of the room. The resistance of the air is increased, as was explained in the preceding chapter, and consequently the flow of fresh air is impeded.

There is yet another evil which is always present where the temperature of the air has been raised after its admittance. This is its increased power of absorbing moisture. Had this occurred prior to its entry, it would have taken the many opportunities of slaking its thirst that present themselves in the outer world; but in the room, the only moisture which it can take up is the natural moisture in the bodies of the occupants. This it absorbs far more rapidly than nature intended, leaving that hot and dry sensation in the throat and lungs, with the after effects which all have experienced whose lot it has been to be shut up in a room under such conditions, particularly if that room has been heated by pipes and coils, and at the same time has been but indifferently ventilated.[1]

[1] The last evil is often combated by the use of a kettle or some such means of evaporating water, and so supplying the air with the necessary increase of moisture. There can be no doubt that such a proceeding mitigates the ills wrought by the system.



A PUBLIC ELEMENTARY SCHOOL

Propulsion System of Warming and Ventilating a School: Basement Plan

Natural Ventilation in Hot Weather.—If we are to understand that ventilation and heating must produce environments to correspond with our physical requirements, then ventilation must be as continuous as our breathing; and the operation which, for lack of a better term, we call "heating", must of necessity include that of lowering the temperature as well as that of raising it. It is true that natural ventilation admits of raising the temperature under certain conditions and of passively allowing an equality of temperature; but as far as cooling the air is concerned, the system stands hopelessly at fault.

If the wind could be compelled to blow in the required direction with the desired velocity, and if the air were clean, and of just sufficient humidity, and at a suitable temperature, perfect ventilation and heating would be always possible, the only question for consideration being the points of application of these natural forces—the positions of the inlets and outlets. But all these things remain impossible while we still use the natural forces in their natural state. By drawing further on Nature's store of energy, and transforming and modifying her forces to our purpose, we are enabled to supply our needs satisfactorily.

By adopting mechanical means, the air supplied by Nature is forced into the building independently of such a fickle agency as the wind. The air is taken in at the place or places selected, and is conducted to the apartments by internal arrangements, just as gas or water is "laid on". The motive force is applied to the air by means of a revolving fan or propeller, which drives the supply into a duct usually situated in a basement. This duct may be regarded as the main artery of the system, and from it secondary or subsidiary ducts convey the air to suitable positions, whence it can be forced upwards through vertical flues to the points of delivery in the walls of the rooms. The air, as taken in at the main inlet (or "intake" as it is technically termed), is so treated in transit as to ensure the attainment of those conditions already named as being the desiderata of proper heating and ventilation. It is screened and freed from suspended particles and impurities, washed and humidified as necessary, and the temperature adjusted (raised or lowered) to the required degree before it is delivered to the consumer, and it is discharged at a prescribed velocity into the room, the uniform temperature of which practically coincides with that of the incoming air, and therefore the presence of a draught, the *bête noire* of the ventilationist, is rendered impossible.

Thus one part of the operation of heating and ventilating is completed, namely, the supply of diluted oxygen at a suitable temperature. The other part—**the expulsion of deleterious gases** and organic matter—follows as a natural corollary. The propulsive force is transmitted by the incoming air, which drives the vitiated air before it till the latter is forced by the pressure through the aperture provided for its expulsion. Thence it is carried by flues out of the building and eventually released, usually from a common "extract". This part of the work may or may not be afforded additional mechanical assistance. If it is, another fan is provided in the extract shaft, and by relieving the column of air contained

therein of part of the external atmospheric pressure, it offers less resistance to the force transmitted by the fresh supply from the intake fan, and is therefore more easily expelled.

Since, as we have already seen, **air under pressure** transmits the same pressure in all directions, the air in an apartment operated upon by such a system is compressed, and exerts itself not only upon the walls, but also upon the windows and doors. This pressure, though not perceptible to the occupants of the building, is sufficient to cause the air to avail itself of any means of egress by openings, however slight they may be, due to defective joinery. Though perhaps not to be reckoned as a total loss to the ventilation of the room, such an escape is a defect, insomuch as the air emitted has not completed its work of pressing on the vitiated air and forcing it towards its proper exit. This loss of pressure cannot be entirely avoided, however well the joinery may "fit", for doors must occasionally be opened, and even the walls themselves are by no means impenetrable,[1] but the loss should be reduced to a minimum.

Therefore it is most important that all **windows** be kept closed, and be fitted as well as possible. The same rule applies to doors and other openings as far as practicable. It is as well, however, under ordinary circumstances, to make the windows to open. This not only renders them the more easily cleaned, but if they are placed in a suitable position for natural ventilation, that system may be resorted to when the building is unoccupied, or when external natural conditions render such a mode satisfactory. The windows, however, should be fitted with such latches or fastenings as require a key for their manipulation, so that irresponsible persons may not interfere with them; for if it is possible to open them in the ordinary way, it may occur that someone in a heated condition (say) in summer, enters the room, and, not content with the moderate temperature of the atmosphere, opens a window. The result is impaired ventilation, and he thereupon opens all the windows, the outcome being that the whole system is thrown out of order, and in his ignorance he has frustrated his own design.

The best form of window, with regard to the possibility of making it air-tight, is the casement. If such a window close into a double rebate instead of the usual single one, and at the same time be well fitted, the passage of air between the sash and the frame is considerably reduced. The sash can be made to draw up tightly by the use of one of the many fastenings on the market, which, acting on the principle of the inclined plane, lock the sash and force it well home at the same time.

As will be seen later, this system of ventilation can be controlled to a degree of almost mathematical precision; but the moment a door is opened the operation, as far as the room affected is concerned, is thrown temporarily out of order, and must remain so until the door is closed. For this reason **doors** which are likely to be left open should be fitted

[1] Pettenkofer found by experiment that the brick walls of a house containing 2650 cu. ft. admitted 1060 cu. ft. of air in forty-eight minutes with no other inducement than the exhaustion of the air by a good fire.

with suitable automatic closing apparatus. When the doors of a large room are much used, and the circumstances will admit, a lobby and a second door are of advantage. But in all cases the corridor or other room with which the apartment in question communicates should likewise be operated upon by the system, in order that the air outside the door may be of about equal density with that in the room, and so prevent the escape which would otherwise occur. Where **the floors** are of ordinary boarding on joists, the boards should be grooved and tongued and well laid.

The walls are worthy of notice, and where the choice is permissible a hard material is preferable to a more porous substance. Keene's cement, brought up to a polished surface with metal trowels, gives a good hard face and renders porous brickwork far more air-tight than it would be, either without any covering or finished with ordinary plaster, and has the advantage of taking paint readily.

Such scrupulous care may seem somewhat exaggerated. In reality it is not imperative that the building should be air-tight; even with the greatest care such a state of perfection is an impossibility; but any extra care taken in preparing the structure in this way for the particular form of ventilation will be amply repaid in the working of the system, for in calculating the supply of air required, this loss (and some loss is unavoidable) must be allowed for according to circumstances. Expedients will suggest themselves to the architect for the closing of all openings through which an appreciable wastage might otherwise occur, the object to be kept in view throughout being the confinement of the air to its proper course from the time it enters the intake till it escapes from the extract shaft.

Another danger in providing for occasional natural ventilation lies in the possibility of the mechanical apparatus remaining idle for sufficient time to allow of the accumulation of dirt and rust, and of the working parts getting out of order. Idleness is generally more mischievous to machinery than work, and this is peculiarly so in the present instance. The apparatus must therefore be worked at stated intervals when not in general use, and special care must be taken to safeguard it against deterioration.

CHAPTER IV

PROPULSION APPARATUS

The Propulsion Apparatus may be regarded as consisting of two distinct parts: the machinery for forming the energy (or to be more correct, for transforming other energy into mechanical energy) and the apparatus for applying that energy to the air and propelling it into the building.

The chief desideratum in this connection is **silence**, and any little extra cost incurred in securing this end may be regarded as money well spent. The objection to any noise from the running of the mechanism will be

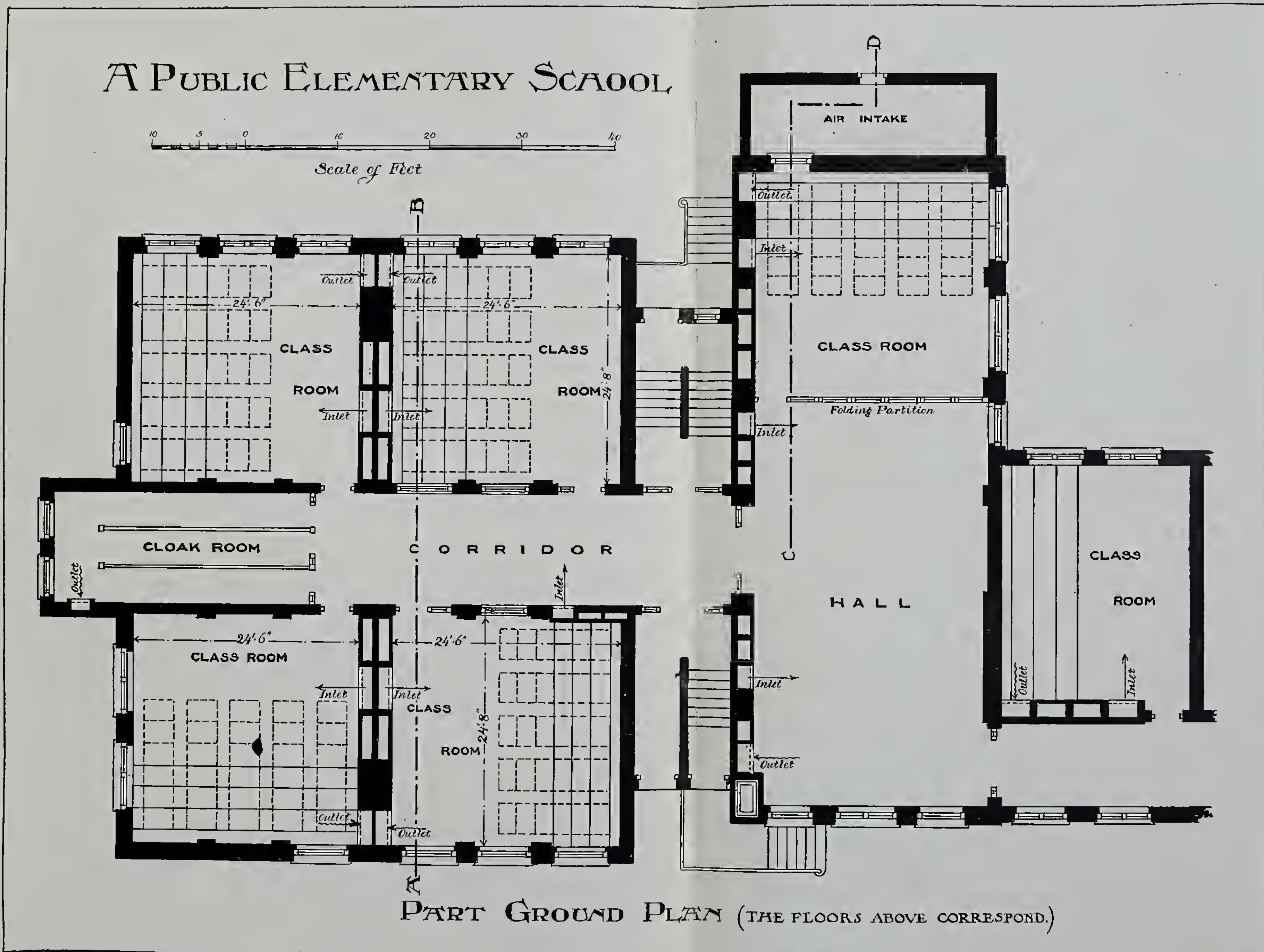
readily appreciated when the mode of communication between it and the rooms of the building is considered. The body of air confined in the ducts and flues is a ready conductor of sound, the more so as the atmosphere is slightly condensed, supercharged with moisture, and moving in the direction of the rooms. Indeed, ordinary conversation is conveyed in this way through the ducts and flues to the rooms, and is distinctly audible to the occupants.

Another objectionable feature in many installations is **vibration**, not of sound waves in the air, but of the structure itself. It may be that the pulsations are so slight in degree as to be imperceptible, and at the same time so rapid as almost to communicate sound to the atmosphere. In any case they are most exhausting to the occupants of the building, and have a tendency to produce headache and a sense of depression, and, as far as symptoms go, have much the same effect as improper ventilation. To avoid this, it is usual in those few cases where neither enforced economy, lack of room, nor exigencies of planning forbid, to place the mechanical apparatus in a separate building and to carry the main duct from it to the main structure. The intake will under such circumstances be at some distance from the main building, and there will be less possibility of the ingoing air becoming contaminated by an admixture of the noxious gases from the outlet shaft. But, unfortunately, such an arrangement is not often possible, for more expense is necessarily incurred in providing means of conveyance of the air to the building; besides which, if the air be warmed, as it often is, by batteries just within the intake, the loss of heat resulting from carrying the supply through a long duct would represent increased expenditure in heating.

The only means that have so far proved successful in driving a steady stream of air noiselessly into a building are **revolving fans or propellers.** There are many types on the market, and as the efficiency and the cost of working an installation greatly depend on this piece of apparatus, too much care cannot be exercised in its selection. Probably the best type is the straight-through volume fan fitted with a peripheral flange. One obtained from a good firm can generally be relied upon to do a stated work when driven at a certain speed by a prescribed power.[1] The bearings should be of phosphor bronze, and it is important that they should be self-lubricating.

There are types of propellers in use having adjustable blades, the pitch of which can be regulated by the manipulation of a set screw, thereby regulating the flow of air. This class of propeller is not to be recommended, as the correct position of the vanes for economical working is a matter of intricate calculation, and should therefore not be left to the discretion of an ordinary mechanic, still less to an unskilled man, such as is often placed in charge of a plenum system. As a more rapid air change is generally

[1] The manufacturers in stating the amount of air propelled always assume the most favourable conditions and a straight blow through. It would not be fair, therefore, to test a fan which is in position in a building where the body of air is forced through a long duct, subjected to considerable friction, and its passage throttled and twisted out of a straight course, for under these conditions the work done in comparison with the expenditure of motive power becomes considerably reduced, and due allowance must be made for them when determining the amount of work required of the propeller.



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required in summer than in winter, it is necessary **to regulate the quantity of air** supplied accordingly. This could be accomplished, of course, by varying the speed of the motor; but it is far preferable to keep it running at its most economical velocity and reduce or increase the number of revolutions of the propeller by lowering or raising the gearing. This arrangement is perfectly simple; all that is required is to fit the propeller with two pulleys of the necessary diameters, when the belt can be adjusted and slipped from one to the other as necessary.

The maximum number of revolutions to which a fan should be geared is a matter of much controversy. While it is advantageous from an economic standpoint to get as much work out of a fan as possible, yet if the blades be made to pass through the air too rapidly their vibration will generate sound waves which will be audible throughout the building, and the more rapid the revolution the higher and louder will be the note created. Save in exceptional circumstances, where silence is unnecessary, such a result would not be permissible. The larger the propeller the faster will the blades travel through the air (the revolutionary speed being constant), owing, of course, to its greater perimeter. It is therefore necessary that a large fan should be driven more slowly than a smaller one. Generally speaking, with fans in the range of sizes usually employed, the maximum number of revolutions per minute should not exceed from 250 to 280.

Motive Power.—The fan may be driven by a steam engine, a gas engine, or an electric motor.

The steam engine, as a motor, is more suitable for the ventilation of factories and works where steam power is readily obtainable, and where there is no objection to the noise of its running. Otherwise it is the least desirable of the three motors named. The chief defect is the noise it creates, which in itself is a sufficient reason in many instances for prohibiting its use. Besides this, there are other disadvantages in the employment of steam where it has to be generated specially for the work. Before the apparatus can be got to work, steam must be got up, a process occupying about three hours. Moreover, the boiler which in other circumstances would be sufficient for heating purposes would be quite inadequate for driving the engine in addition, and a much higher pressure of steam must be maintained. Then when the heating apparatus is not required, the boiler, unnecessarily large for the work of ventilation alone, has still to be fired, at an extravagant expenditure of coal, to work the fans—the only alternative being to provide a secondary boiler of smaller dimensions for summer use. This would, of course, represent a considerable increase in the initial cost, besides occupying additional boiler-room space. Furthermore, a steam engine cannot in safety be left to the care of any but a skilled mechanic.

The gas engine provides a far preferable means of supplying the necessary power, and at the present day it is scarcely possible that an edifice of such size as would warrant the installation of a plenum system can exist where gas is not ready to hand. Indeed, there are probably more buildings in England ventilated in this way than by any other mechanical means. The gas motor is smooth and comparatively quiet in its action,

seldom getting out of order, requiring little attention beyond that necessary to start and stop it, and it can therefore be tended by a caretaker or any other unskilled hand. The initial cost is not great, nor is its working expensive, and the latter is further curtailed by the fact that it can be started whenever required, without any preliminary wastage, and that immediately it is stopped all running expense ceases at the same time.

There are many types of gas motors on the market. One of the modern modifications of the "Otto" engine is as suitable as any for the work. It is conducive to a perfect balance and smooth working to select a model having two fly wheels.

Whatever model be chosen, it must be remembered that it is designed to run at a certain speed, and the number of revolutions prescribed by the manufacturers should be strictly observed in the working of the engine, and therefore all calculations must be based on that speed. To drive at a higher rate would necessarily increase the vibration, besides placing undue stress and wear on the parts and so shortening the life of the engine, whilst to run at lower speed would not be consonant with the most economical working of the motor.

There is a great temptation in the case of a gas engine to select one just sufficiently powerful for the work and no more, owing to the rapid increase in price with the additional brake power provided for. Thus an engine of 4 brake power would cost about 20 per cent less than one of 5 brake power, and so on. It is very important that the engine provided should be of a size capable of easily performing all the work that is likely to be required of it. This is not confined to gas engines, but is equally applicable to whatever form of motor is used. The saving effected by choosing an engine too small or barely capable of performing the work is a false economy in the end, as it shortens the life and adds very considerably to the cost consequent on the wear and tear of the engine, besides increasing the noise and vibration. A safe practice is to specify an engine capable of performing the required work if driven by the gas of the locality, when one charge is cut off by the governor out of every possible four—in other words, allow for an overload of 25 per cent.

Where an engine exceeds 12 brake horse power it will be found too heavy to start by hand in the usual way, and should therefore be fitted with a self-starting apparatus. An important point with regard to the fixing of an engine is its bed. It is often placed on a stone base or concrete floor laid directly on the ground, and sometimes even partly on the foundations of the building. The consequence is that whatever vibration there may be is transmitted immediately to the structure. Now if a good bed be provided sufficiently sound not to be disturbed by the movement of the mechanism, and at the same time just sufficiently yielding not to conduct the vibration, the engine is in a sense insulated. A foundation of timber under the stone or concrete base is found to answer the purpose admirably.[1]

The repeated explosions in the cylinder of a gas engine give off a certain

[1] An excellent foundation can be formed of two layers of railway sleepers, the top row being laid transversely to the lower, and the whole surmounted by a bed of concrete. The railway sleepers have the advantage of having already been treated with creosote.

percentage of energy in the form of heat to the cylinder. In any gas engine of over 2 or 3 brake power this heat is so intense that the small surface presented by the cylinder is insufficient to get rid of it by radiation, and were other means not resorted to, the effect of the heat would be disastrous to the working parts in its vicinity. The cylinder is therefore enclosed in a "jacket", and a constant flow of water is passed through the intervening space, thereby reducing the heat by the more rapid method of convection. The water is conducted by a pipe from a cooling tank to the cylinder and back again, on the common principle of flow and return.

In this connection, too, a form of false economy is often practised by providing tanks of insufficient capacity. This defect has to be compensated for by running fresh cold water into the tanks, and, of course, allowing a corresponding amount to run to waste. In many instances the additional working expenses thus caused exceed in a very short time the extra initial cost of supplying adequate tanks. A tank or series of tanks should therefore be provided of sufficient contents to ensure at all times a constant supply of water to the cylinder at a temperature not exceeding 70° F., without the introduction of cold water to the service from an external source beyond what is required to make good the slight loss by evaporation.

In the working of a gas engine the unburnt gases are released and discharged into the open air through an exhaust pipe. As some of the gases are of an extremely noxious nature, they must therefore be ejected at a position from which they cannot by any means find their way again into the building. As the exhaust gases are released at a high pressure, it is necessary to pass them through an "exhaust silencer", a simple contrivance which lessens the noise otherwise attendant on the violent emission of gases at a high velocity through a small bore.

The electric motor is by far the best for the purpose, and neither steam nor gas should be used for propulsion in a case where electric cables are laid in the immediate neighbourhood. The electric motor is capable of high velocity, works uniformly, and practically silently. It takes up little room and can be fixed anywhere. It also has the advantage of not emitting anything in the way of exhaust, and requires no water service to cool it, as does the gas engine. The mechanism is so simple and the parts so few that there is little essential difference in the various motors suitable to the work. Preference might be given, however, to the semi-enclosed type. The motor should be of ample brake power for the work, and when running continuously at full load there should be no suspicion of sparking at the brushes. The temperature on the winding should never rise above 40° C., while the maximum temperature allowable for the commutators should be 45° C.

But if the electric motor is the most advantageous apparatus for propelling the air into the building, its superiority is still more apparent for operating a fan in an extract flue. Where only steam is used, the idea of placing an auxiliary fan in this position is, for obvious reasons, impracticable in all ordinary circumstances. It is quite feasible to drive a propeller in the main extract by means of a gas engine, though a considerable amount of special construction will be necessary to carry a live load at such a

height, and no matter how carefully the work may be done it is very questionable whether the engine, thus brought into direct contact with the structural fabric, will not communicate vibrations to at least the nearest rooms. With electricity it is as easy and as safe as regards vibration to place a motor here as in any other position, and owing to its lightness, and the uniformity of its movement, little or no special construction is necessary, and indeed what little weight there is may almost be treated as a dead load.

In short, electricity is an ideal form of energy for the purpose of mechanical ventilation, and should always be utilized when it is available.

CHAPTER V

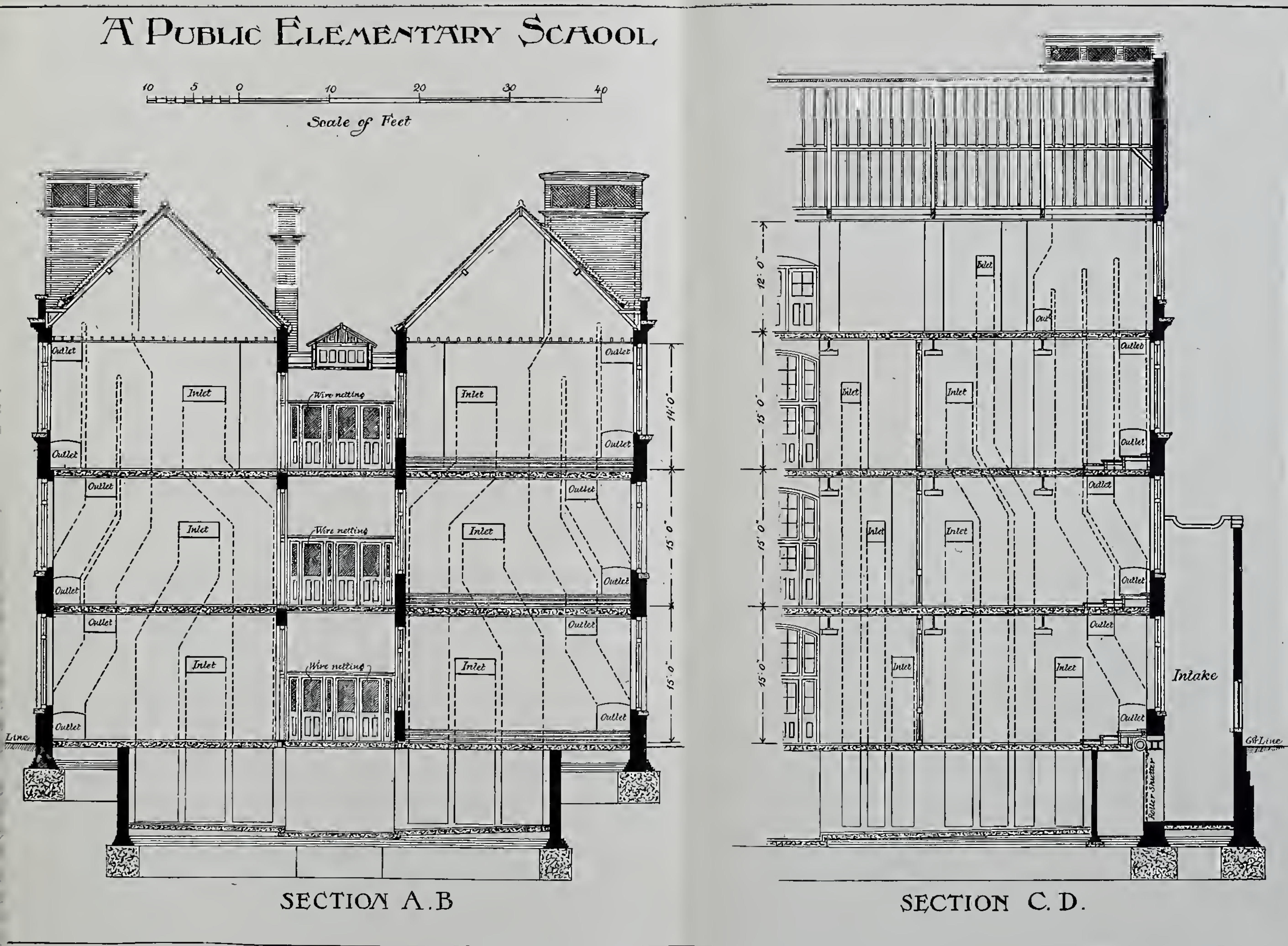
SCREENS AND HUMIDIFIERS

Intakes.—To ensure that the air shall be as clean as possible before its entrance into the building, it is usually taken in through an intake shaft, which is a large enclosure formed by brickwork, and rising at least 10 ft. above the ground level, or more if circumstances require (see Section C D, Plate XXVII). The effect of this is to exclude the débris and dust which lie on or near the surface of the ground.

But though this must undoubtedly keep away much of the dirt, and possibly paper, leaves, and rubbish that would otherwise enter the building, it is by no means sufficient protection against the many impurities with which the air of our cities and towns is laden. To prove this it is only necessary to examine a screen used to filter the air propelled into a building after it has been in use an hour or two, particularly if no water is allowed to run over it during that time. In no other way than by ocular demonstration can one be expected to believe that the air contains such an amount of soot and other impurities of a solid nature.

Canvas Screens.—In the early days of mechanical ventilation the air was passed through a screen of loosely woven canvas or cheese cloth. This acted as a fairly good filter, but it soon became clogged with the accumulated filth which even the provision of a sparge pipe could not entirely obviate. Moreover, the material itself was not very durable, and this mode of screening has long since fallen into disuse.

A far better application of the method of filtration by means of a fixed screen was afterwards employed in the form of stout strands of fibre fixed at the top and bottom and connected together at regular intervals. The hairy nature of this material, while providing an excellent obstruction to floating particles, tends to prevent their rapid accumulation in a dense mass on the surface of the screen, which would impede the passage of the air through its interstices. The great defect is the difficulty of removing the impurities from its surface. A sparge pipe is generally fixed above it, and periodically sprays the outer face of the screen, which is usually fixed in such a way as to incline inwards at the top in order the better to bring the



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whole of the surface under the influence of the wash. To be of any use at all, a considerable amount of water must be released at each discharge, which necessarily runs to waste. In a very little time a distinctly sooty odour is given off, which seems to be unavoidable. Even were the sparge allowed to discharge continuously, which would mean an extravagant expenditure of water, the surface of the screen would not remain clean, as will be readily understood when it is stated that a free use of the hose and brush is unavailing in detaching the soot and other particles of dirt from the clinging embrace of the fibres. The evil is mitigated to some extent in more recent installations where this screen has been used by fixing it in small bays, which are easily removable for cleaning purposes; but probably in no case can this screen be regarded otherwise than as dirty and giving very unpleasant results.

Coke Screens.—Another form of fixed screen, which is preferable from the point of view of cleanliness, is the "coke screen". A double iron frame covered with wire netting is filled with small coke, the frame being made in such a shape as to hold the coke in the form of a screen from 4 to 6 in. thick. A sparge pipe, discharging intermittently over the coke, does much to cleanse it, and also assists in presenting a better surface for the arrest of impurities. It also has the advantage of an inexpensive renewal; but this screen cannot be recommended, as to filter the air effectually it is necessary to pack the coke so closely that it seriously impedes the flow, and places extra work on the fan.

Disadvantages of Fixed Screens.—Besides what has been already stated, all fixed screens have a disadvantage in common. It is now generally regarded as the duty of the filtering apparatus not only to arrest the impurities contained in the air, but to give it that extra degree of humidity which shall neutralize its increased absorbent qualities when its temperature has been raised. The periodical flush from the sparge pipe, if sufficient to saturate the screen thoroughly, performs this work but for the moment. As we have already seen, the power of absorption possessed by the air (unless already charged to saturation) is greatly increased by rapid motion. It therefore follows that the air, rushing through the screen at a high velocity, takes up all the moisture almost immediately. Under these conditions the quality of the supply passing into the building cannot be constant, but the occupants of the room experience an atmosphere at one time humid, and at another arid and disagreeable. To remedy this by the use of a constant flushing of the screen would be, as already pointed out, too expensive to be seriously considered.

Movable Screens.—This difficulty is successfully met by the use of one of the movable screens which, instead of being occasionally washed by the discharge of water upon their surface, are continuously passed through a trough of water, and so kept thoroughly wetted.

A simple contrivance of this kind is formed by passing the plaited fibre over a roller at the top of the aperture and under another at the bottom, then joining the ends of the material, and so forming an endless band over the two rollers. One of the rollers is operated by a low gearing from the motor, which turns the whole screen about twice a minute. The bottom

roller turns in a trough of running water about 4 in. deep, which is fed from a bib cock, so that the material, which is thus kept continually wet, transmits a uniform degree of humidity to the incoming air. By using such an apparatus, the air passes through two thicknesses of the material, which perhaps is an advantage in one way—should any impurities pass the outer thickness, they will perchance be stopped by the second. But in practice this cannot be regarded as an unqualified advantage. If the fibre be so loosely woven as to allow suspended bodies to pass it and find a lodgment on the second thickness, they are likely to remain there; for as that portion of the screen passes through the water in the trough, it will have the pressure of the lower roller on it, and whatever impurities may be clinging to the inside—that is, the roller side—of the material will be the more firmly embedded in it after its immersion. On the other hand, if the consistency of the fibre be such as to prevent any foreign particles from passing through it, a double thickness of such material would present an unnecessary resistance to the air, and so place undue work on the propellers without any corresponding advantage accruing. Another disadvantage attending the use of this screen lies in the fact that the continual movement of the fibre over the rollers under a certain amount of tension necessitates frequent repairs and renewals.

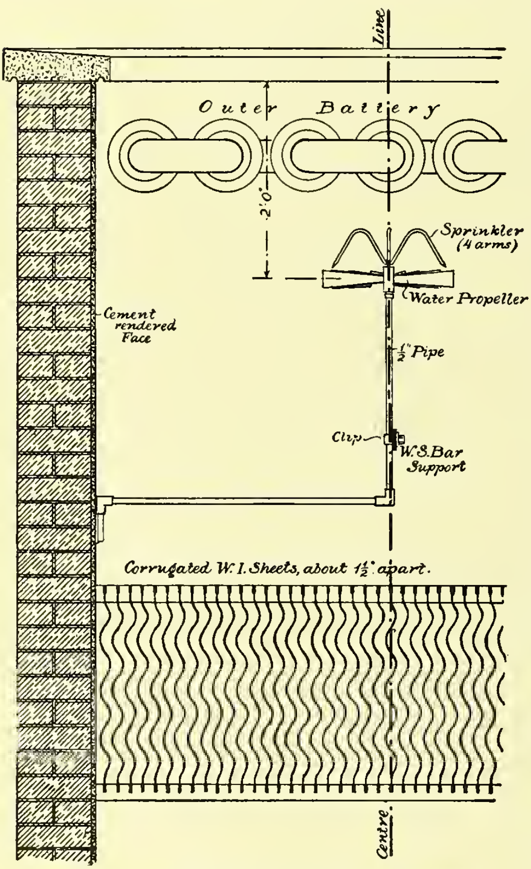
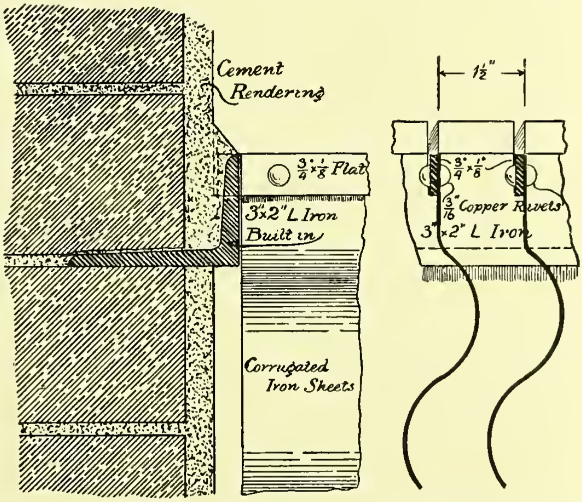


Fig. 435.—Section through part of an Intake, showing Mist Screen Apparatus

Drum Screens.—A better screen is one which is made in the form of a large drum with one end open. It is constructed on a frame of light steel, and covered with the plaited fibre before described. The drum is made to revolve on an axle with the open end of the drum turned towards the duct. Here again the motor is engaged to work the apparatus, the gearing being so low (about five revolutions per minute) that practically no extra load is placed on the engine. The lower side of the drum dips into a brick-built trough containing running water. This keeps the fibre wet and constitutes a good humidifier, besides doing something in

the way of removing the accumulation of deleterious substances from the material. It necessitates, of course, a certain amount of waste of water; but this is trifling when compared with what would be lost through a discharge from a sparge pipe sufficient to keep a fixed screen wet. Altogether, the revolving cylinder may be regarded as the best form of fibre screen and the most economical; but, in common with all the fibre screens, it shares their defect in the tenacity with which it holds the impurities collected on its surface. No fibre screen, after having been used for any length of time, is free from a pronounced sooty odour.

Mist Screen.—Probably the best means yet devised for cleaning and humidifying the air is by passing it through a mist screen (fig. 435). This operation is performed in the intake shaft. The mist is created by water which, on being discharged from a four-armed sprinkler, impinges on the blades of a revolving screw. The sprinkler is fixed about 2 ft. below the top of the intake, and the screw, which is of copper, is immediately beneath it and is so fitted as to be turned freely by the water falling upon its blades. The effect of its motion is to throw the water off in all directions in the form of a fine mist, which completely fills the intake. The air necessarily passes through this, with the result that any suspended impurities are coated with the moisture and fall to the ground by virtue of their increased weight, in precisely the same manner as rain is formed by moisture seizing upon floating particles of dust.



Section through Wall of Intake

Section through Corrugated-iron Sheets

Fig. 436.—Details of Corrugated-iron Screen

To ensure that the air shall be thoroughly washed, it is further passed between a number of sheets of galvanized corrugated iron (fig. 436), which are fixed in vertical positions about 3 ft. below the sprinkling apparatus and about $1\frac{1}{2}$ in. apart, and in such a manner that the corrugations, which run horizontally, correspond in position on the various sheets. A good method of fixing the sheets is shown in fig. 436. The L-iron is slotted to receive the $\frac{3}{4}$-in.-by-$\frac{1}{8}$-in. flats to which the corrugated iron sheets are attached. The slots must be made to fit the flats, so as to prevent rattling when the air passes between the sheets. The cement behind the L-iron should be slotted out whilst it is green. The sheets are fixed to L-irons at the bottom in a similar way.

In passing between the sheets, the current of air is split into a number

of laminæ of a section represented by a series of reflex curves. The oscillation of the atmosphere so caused not only assists its particles to find and combine with those of the mist, but ensures that at one time or another they must come into contact with the wetted surface of the iron sheets. The impurities arrested find no lodgment on the hard, smooth face of the metal, as they do in the case of the fibre screen, but are washed off by the water from the sprinkler, which constantly runs down, and eventually they drop, by reason of their increased weight, to the floor of the shaft, and thence are carried away by a drain laid for the purpose. By this means, the air passing into the building is thoroughly washed, and is, moreover, amply humidified by the aqueous particles borne along with it.

The advantages of this form of screen will be obvious. The water consumption is small, the extra resistance to the air is hardly appreciable, and the apparatus cannot become clogged with soot. The iron sheets will last for years, and can always be replaced without trouble and at very little cost. In summer, when the heating apparatus is not at work, the cooling action of the mist will be found sufficient to reduce the temperature of the air several degrees. This cooling effect is more pronounced in the use of the mist screen than of any other, and generally the temperature of the atmosphere when delivered in the rooms will not be too high, even in hot weather. A greater reduction in the temperature can be made by passing the air over ice if desired; but for ordinary purposes such a practice will not prove necessary.

Humidity of the Air.—There are some days in every summer when the natural atmosphere is already saturated with moisture—such days when the weather is characterized as "close and muggy". The real effect is that the air, being already burdened to the point of saturation, will not absorb more moisture, and consequently the function of perspiration is retarded and becomes "conscious", owing to the difficulty experienced in ridding the skin of the excreted vapour. In consideration of this fact, it might appear at first thought that, however desirable it may be to impart extra humidity to the air under certain conditions, to drench it with water when it is already saturated would be detrimental to the quality of the supply and would increase the discomfort of the occupants of the building, more particularly when such a thorough humidifier as the mist screen is employed.

If the facts be examined more closely, however, it will be seen that such is not the case. The air, when it enters the intake shaft, being already at the point of saturation, is incapable of taking up any more moisture, unless its powers of absorption are increased by raising its temperature. But on the contrary, its absorptive power is reduced when it is brought into contact with the cold mists. This has the effect of lowering the point of saturation, so that, paradoxical as it may seem, by passing the atmosphere through cold water or vapour, the superabundant moisture is in reality extracted. The air then passes into the main duct, saturated still it is true, but at a lower point of saturation. On its way through the ducts and flues to the points of delivery there is necessarily a rise of a few degrees in the temperature from its contact with the surrounding material. Its power

of absorption is thereby increased, but there is now no further means of its satisfying its thirst, and therefore, on delivery, it is rendered capable of further absorption.

In this way, by giving the air ample opportunity of taking up moisture as it enters the building, the screen regulates its condition automatically. When too dry, it becomes humidified to a desirable degree, while, when it is saturated, its humidity is reduced in the manner described. With this reduction, the state of the atmosphere ceases to be "muggy", whilst, by virtue of the increased velocity usually given to the air in the summer months, its drying quality is still further enhanced.

Position of Screen.—Whatever form of screen may be selected, it is preferable to place it on the *outside* of the fan. By so doing the air is allowed to pass through the screen under the atmospheric pressure, or, to put it into common (though incorrect) parlance, the air is *sucked* through. This is a decided saving of power, as all the air on the building side of the fan is in compression, while that immediately outside is somewhat rarefied, and it is apparent the screen would offer more resistance to the air if in the denser state. The relative positions of the fan and the screen are therefore a question of some importance, for the resistance of the screen—particularly if it be of the "fibre" or "coke" type—is a matter to be reckoned with.

CHAPTER VI

DUCTS AND FLUES

Simplicity in the arrangement of the ducts is an important factor in the success of a scheme, as all unnecessary lengths of conduit and superfluous bends impede the flow of the air, and consequently throw more work on the fan, which in turn demands an engine of greater brake power to revolve it at the necessary speed, in order to propel the air supply calculated for.

Some of the advantages of placing the mechanical apparatus, together with the intake, in a separate building have already been mentioned. To these may be added the fact that by such an arrangement the main duct may sometimes be designed to give the supply a straight run from the intake shaft to the subsidiary ducts, where the general plan is such as to prohibit this desirable achievement did the intake adjoin the building. It sometimes happens that the only possible position for the intake lies in a long side of an extended plan, thereby necessitating the main duct's running at right angles to the axis of the propeller, as shown in Plate XXIV. In this case a blank wall, forming the side of the main duct, stands immediately opposite to the two propellers, and necessarily reacts on the air and effectually retards its velocity. Such a loss of energy would not have arisen had it been possible to place the intake at one of the flanks of the building, and so to have driven the air directly along the main duct. This effect is attained in the plan of the basement shown in Plate XXVIII.

Where the intake unavoidably comes at right angles to the line of the

main duct, the resistance to the influx of air may be avoided (or, more correctly, minimized) by an arrangement similar to that shown in Plate XXV. In this plan the scheme is divided into practically two distinct systems, **two propellers** being employed, one to feed the duct running in one direction and the other to supply that in the opposite; and in this way the air is driven from the propellers straight along the ducts. It is perfectly true that the course of the air is turned at right angles just the same, but in this instance it is the rarefied air approaching the fan that receives the check to its momentum, which is a trifling loss to the supply when compared to what it would have been had it occurred to the compressed air already past the propeller.

In this particular instance the position of the intake holds a distinct advantage over a position at the end of the building, for exigencies of the plan necessitate the running of the main duct in two different parallel lines, which would have resulted in a double break had the ducts been run into one and the air propelled from this end. The supply to the two fans is divided by a partition. This is very necessary in a case of this kind in order to prevent the working of the fans affecting each other.

What has been said of the ill effects attending the use of **sudden angles** applies throughout a scheme. When they occur, it is necessary, for economical working, to make the bends as easy as possible, or, what is in effect the same, the passage should be so enlarged as to minimize the extra resistance.

Another source of a retarding force is **friction.** Ventilationists are apt to regard this force in too light a manner. Air, as we experience it in our personal movement, seems so perfectly fluid and yielding as to be devoid of friction; but if we regard the motor driving the air through the building, and then think that practically the whole of its energy is expended in overcoming the friction opposed to atmospheric motion, we can form some estimate of its retarding influence, even as presented by the passing of the molecules of compressed air over the surfaces of the ducts and flues. The friction over these surfaces is influenced in two ways: by their smoothness (or otherwise) and by their extent in relation to the amount of air they pass—that is to say, by the sections of the ducts.

The material most generally used in **the construction of the air passages** is brick, as it is usual to take advantage of the structural formation of the building to economize in this matter; for instance, the main duct shown in Plate XXV is really a basement under the corridor of the ground floor (see Plate XXVI). The flues are formed in the walls, which are thickened out as necessary to contain them, and these conditions, of course, influence their sections. In reality the most economical section, as regards the transmission of air, is circular; the resistance of a round tube is only seven-eighths of that of a square one of the same area, and still less in proportion to an oblong section. But, in the circumstances, the circular section is generally impracticable.[1] In employing the oblong section it must be remembered that the greater the difference between the two dimensions representing the

[1] In some buildings, such as factories, where large projections from the walls are not objectionable, the flues might be formed of large stoneware or sheet-metal pipes.

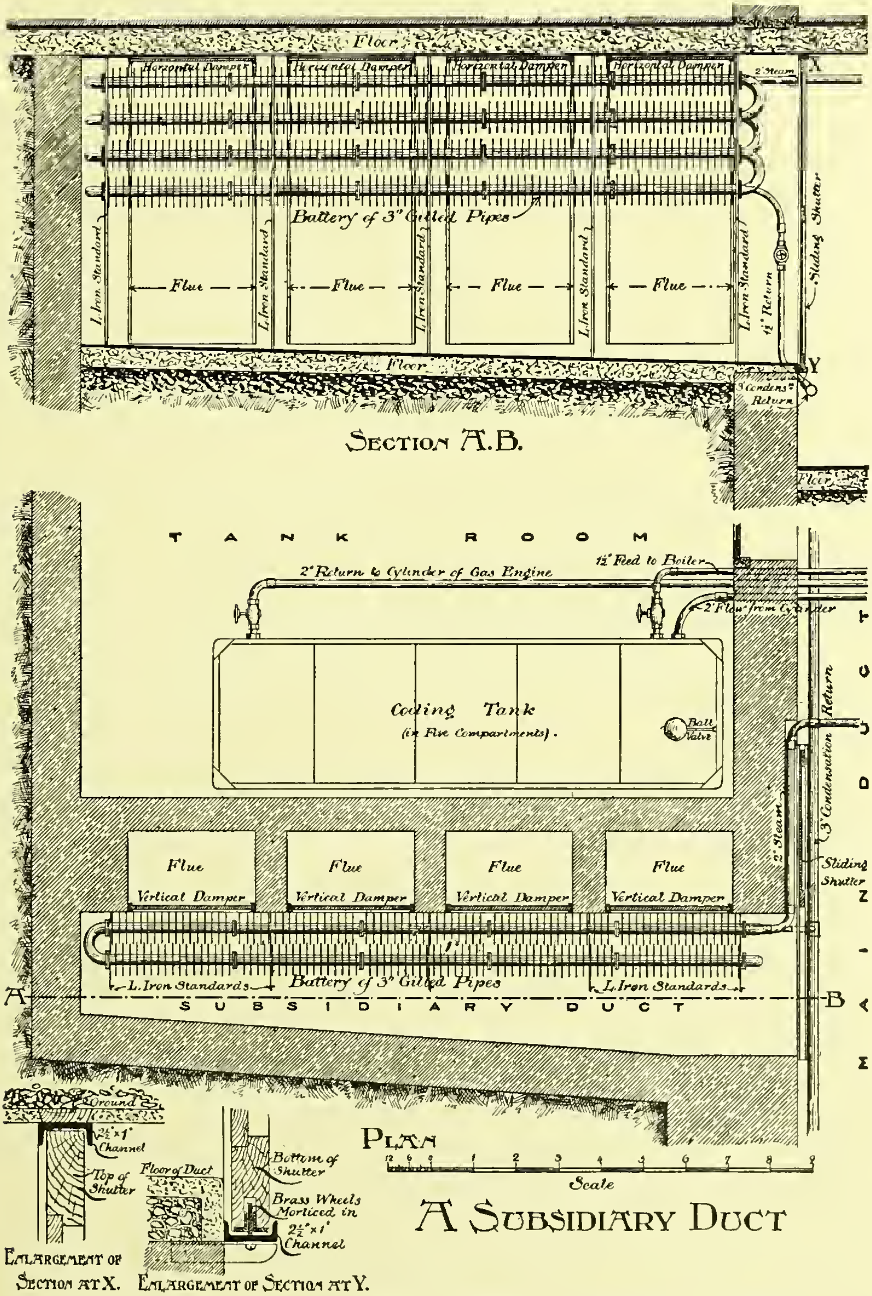


Fig. 437.—Plan, Section, and Details of a Subsidiary Duct (shown next "Tank Room" in Plate XXVIII)

section the greater will be the resistance. Thus, for instance, a flue 3 ft. × 1 ft. 6 in. would be far preferable to one 6 ft. × 9 in., though the latter section might appear more suited to its position in the thickness of a wall.

It is a common practice to **render in cement mortar** the interior of the ducts and flues. This makes a good sound job; and if the work is well trowelled with metal trowels and wetted the while, a hard smooth surface can be obtained, which not only offers little resistance to the air, but is easily cleansed, which is a most important consideration. The cleanliness can be further augmented by rounding out the angles in the cement to a radius of (say) 3 in. There is one disadvantage in cement rendering, more particularly in its application to flues. The flue is built little by little, and the rendering has to be done by degrees as the work proceeds. It is therefore difficult to avoid dropping the cement on the work already finished and set lower down the flue. Were this surplus cement allowed to lodge there, the internal face of the flue would be so rough as not only to impede the passage of the air, but also to harbour dirt. The use of cement for this purpose therefore demands the strict supervision of the clerk of works. Ready access to the ducts should be preserved throughout, and a sweep's brush and canes should be at hand to remove immediately any accumulation from the finished work.

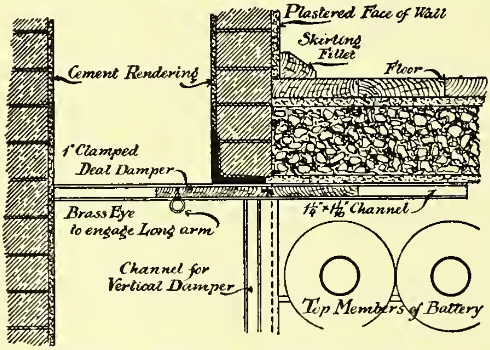


Fig. 438.—Base of Flue, showing Horizontal Damper

If not too expensive, it is more advantageous to face the ducts and flues with **glazed bricks** in cement. These afford a smoother and cleaner surface.

Every facility should be afforded to keep the whole of the ducts and flues scrupulously clean. To this end it is essential to lay **the floors** of the ducts to falls running into properly trapped and drained gullies, and stand pipes must be fixed in suitable positions for the use of the hose.

Each flue should be fitted with a **horizontal sliding damper** at its base (see figs. 437 and 438)—that is, where it rises from the duct. By this means it is possible to regulate the air supply of each room to the extent of shutting it off altogether, without interfering with the ventilation of any other part of the building. These dampers may be made of deal. It is not essential that they be fitted to close perfectly air-tight, though they should be made to fit to such a degree as to ensure their doing their work satisfactorily, and not to bind when moved. This and any other woodwork used in the ducts and flues should be well painted, or similarly protected from the action of the water used in washing down.

Besides the dampers to the individual flues, it is useful to have **a sliding door or shutter** to each subsidiary duct, which, when closed, separates it from the main supply (fig. 437). This makes it possible to cut off the set of rooms supplied from the subsidiary duct without manipulating the individual dampers. It is unwise to move the dampers more often than necessary after they have been adjusted to suit the convenience of the occupants of the various rooms; therefore, when it is desirable to stop the

supply to certain rooms, this should be done where possible by the use of the sliding doors, the dampers remaining in their proper positions.

Doors or shutters must also be provided at the **external opening or intake,** to close in the ordinary way of shutting up the building. (See Plates XXIV and XXVII.)

The extract flues may be carried up separately or collected together in groups, rising in single stacks after the manner of smoke flues, or (better still) they may be taken up into a common trunk in the roof, which in turn discharges through a common shaft. This last method affords a good opportunity of fitting an auxiliary fan for assisting in the discharge of the vitiated air. Whichever mode is employed, the outlet should be carried up well above the highest part of the building, and also higher than any adjoining building. (See Section A B, Plate XXVII.) It is just as necessary here, as in the case of a smoke flue, to avoid a down draught—not that the wind would ever blow down the flue with sufficient force to reverse or even stop the mechanical circulation, but it would certainly impede the expulsion of the foul air and generally make the air change irregular and uncertain in its quantity. Then, again, it would scarcely be charitable to release the sewage of our ventilation in such a place that it could be borne by the breeze through the windows or doors of the adjacent building, should our less fortunate neighbour be relying on those openings for his only air supply. Moreover, by being discharged at a good height, the vitiated air will be diffused before it has time to cool and fall to the ground, or, worse still, to find its way round again to the intake. It will be necessary to cover the external openings of the extract shaft or flues with wire netting, or some such protection against the entrance of birds.

Where arrangements have been made to have **recourse to natural ventilation** at certain seasons, a trap door should be supplied to the extract shaft, with suitable gearing, operated from some convenient place in the building. Without such a provision, when the windows are opened the extract flues may prove an annoying source of draughts.

So far it has been assumed that the building is a new one, and that the installation of the ventilation system will form part of the building operations. In the event of **installing a system into an existing building**, matters will necessarily present increased difficulties at every turn, but probably the greatest will arise in the work of forming the ducts and flues. In such cases, constructions in wood are sometimes resorted to, but this material cannot be recommended. If used, the work must be properly glued and tongued at all joints, and very carefully put together, and even then there is always a probability that leaks will appear from straining under the pressure, or shrinkage from the passage of warm air, or from twisting and warping through the use of the hose if the washing process be carried out as it should. Besides these drawbacks there would exist a distinct danger in the event of fire. Sheet iron is certainly better than wood in some respects, though, if unprotected, rust would soon attack the interior of the flues and ducts, and form an excellent resting place for dust and such of the finer impurities as may find their way through the screen. Further, the metal, under the stress of the enclosed air, and influenced by the

variations in temperature to which it is subjected, occasionally emits startling noises.

If a building is worth the expenditure necessary to the installation of a plenum system, it is by far the best thing, if possible, to build proper brick conduits, cutting into the existing brickwork if necessary, and bonding the new to it, and, in short, making a good job.

CHAPTER VII

HEATING APPARATUS

In some of the earlier installations the air was heated by means of a **coke heater** situated near the intake. This has one (and probably only one) point in its favour—that is, cheapness; but it cannot be recommended, except in those special circumstances where air is required irrespective of its quality as a necessity of animal life. It would serve, for instance, in the heating and ventilation of drying rooms; but in the case of supplying human beings, the coke heater is so liable to burn the air, charging it with carbon monoxide, and thus rendering it almost unfit for breathing, that its use is now entirely discontinued, and steam apparatus has taken its place.

Where the propeller is driven by steam power, **the steam boiler** will have a double work to perform, propelling the air into the building, and also warming it. In that case it will be necessary to provide a boiler of the necessary power which will be capable of generating and working at anything from 40 to 80 lb. pressure; but where the propeller is driven by a gas or electric motor, a much smaller boiler will answer the purpose, and need not register more than from 3 to 5 lb. The half-tubular and multitubular boilers, owing to the extent of their heating surfaces, generate steam very rapidly, and have also the advantage of being put together in sections; but they are not as durable as could be desired. For an all-round serviceable boiler one of the simple "Cornish" type[1] cannot be easily beaten. This is a horizontal cylindrical boiler fired in an internal tube. When it is necessary to have a boiler so large that the size of the tube required to supply sufficient grate surface would be a source of weakness, two tubes are used instead of one. This modification of the "Cornish" boiler is known as the "Lancashire" boiler. These boilers are economical in working, last well, and need little or no repairs.

An automatic regulator[1] should be fixed to the boiler. This is a simple device whereby a steam pressure above a prescribed maximum actuates a lever that opens the check damper in the smoke nozzle at the back of the boiler, thus checking the combustion, and at the same time closes the draught damper in front of the ash pit. In this way, as soon as the gauge registers more than the required pressure of steam, combustion is reduced. On the other hand, as soon as the pressure returns to the required limits, the operation is reversed, and the fire is allowed to draw up again. All

[1] For these and other details of steam heating apparatus, see Section XII.

that remains to be done by the stoker is the addition of sufficient fuel when required, which can be done by an unskilled hand.

The transmission of the heat to the air is usually accomplished by means of "**steam batteries**", consisting of a number of lengths of steam pipe (with the necessary **U**'s to connect them), through which the steam is made to pass in order to heat the requisite area of radiating surface in the locality where it is required to raise the temperature. Coils or radiators may be used, but from personal experience the author has found the most economical and perfect mode of delivering the heat is by means of batteries composed of 3-in. gilled pipes (see fig. 437). The large calibre of the pipes reduces the possibility of their corroding or rusting through, whilst the gills constitute a greatly increased radiating surface. The batteries are placed in the ducts. Sometimes the air is heated by a main battery situated just inside the air-purifier, sometimes by a battery in each of the subsidiary ducts (fig. 437), or by small coils in the bottoms of the flues, and sometimes by a combination of these methods.

In the working of steam apparatus it is impossible **to regulate the temperature** by the adjustment of the valves. The pipes must be kept entirely open or completely closed; any half-measures in the manipulation of the valves would lead to an increased accumulation of water in the pipes, which would come into conflict with the circulation of the steam and possibly cause a stoppage. Therefore other means must be adopted to control the temperature of the air supply. Plate XXIV shows a basement heated by means of a battery just within the screens, this battery being augmented by other batteries in the main duct and small ones placed in some of the flues. Separate channels are formed for the passage of the air, and are provided with doors. By opening these a portion of the air passes into the building without coming into contact with the main battery, and so dilutes the hot air by an admixture of cold and thereby reduces the temperature; whilst, of course, by closing the doors, the whole of the air admitted is heated. A somewhat similar device is resorted to in the case of the auxiliary coils in the main duct. These are kept up and by-pass doors hung under them. The disadvantage attending this method of heating lies in the fact that a certain amount of heat acquired by the air in passing the main battery must necessarily be lost before reaching the flues, by the contact of the air with the walls of the ducts, and this detracts from the economical working of the scheme. Another drawback is that the regulation of temperature affects all the rooms in the building equally, and no plenum system can be called satisfactory which does not provide means of modifying the temperatures of the various rooms according to the requirements, or even the idiosyncrasies and fads, of the occupants, without interfering in any way with the remaining sections of the system.

Some ventilationists divide the ducts into two parts by the introduction of a horizontal partition, the end in view being to pass the hot air through the top duct and the cold through the lower, and by means of adjustable dampers to admit the currents to the respective flues in the necessary proportion to result in the required temperature. But it seems quite unnecessary to divide the ducts in this manner, as heated air will naturally rise to

the top of the duct, whilst the cooler current will gravitate to the bottom. Moreover, the partition adds unnecessarily to the initial cost, and at the same time reduces the height of the ducts to such a degree that, in the case of ducts of the usual dimensions, there would not be sufficient head-room for the caretaker to pass through them in anything approaching a position suitable to the due performance of his duties.

The most economical and perfectly adjustable system is that in which the coils are placed in the subsidiary ducts at the bases of the vertical flues. Such a scheme is illustrated in detail in Plate XXVIII. The position of the coils causes reduction to take place close to the flues, so that the air is delivered with the maximum amount of heat. The means of regulation are applied to the flues individually. The batteries are fixed at the top of the ducts against the mouths of the flues, and a vertical sliding damper (fig. 439) is provided to each flue. By raising the shutter the air passing the battery is shut off, and the cold air, which naturally flows at the bottom of the duct by virtue of its greater specific gravity, enters the flue. By lowering this damper to the bottom, only the heated air is admitted, and between the two extremes the temperature can be adjusted to any degree by placing the damper in the necessary intermediate position, which will allow two currents to pass—one hot and the other cold—in exactly the required proportions, which will afterwards mingle in the vertical flue, the manipulation of these dampers merely affecting the temperature and not the volume of the delivery.

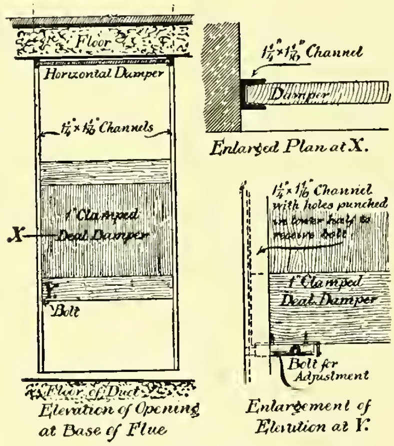
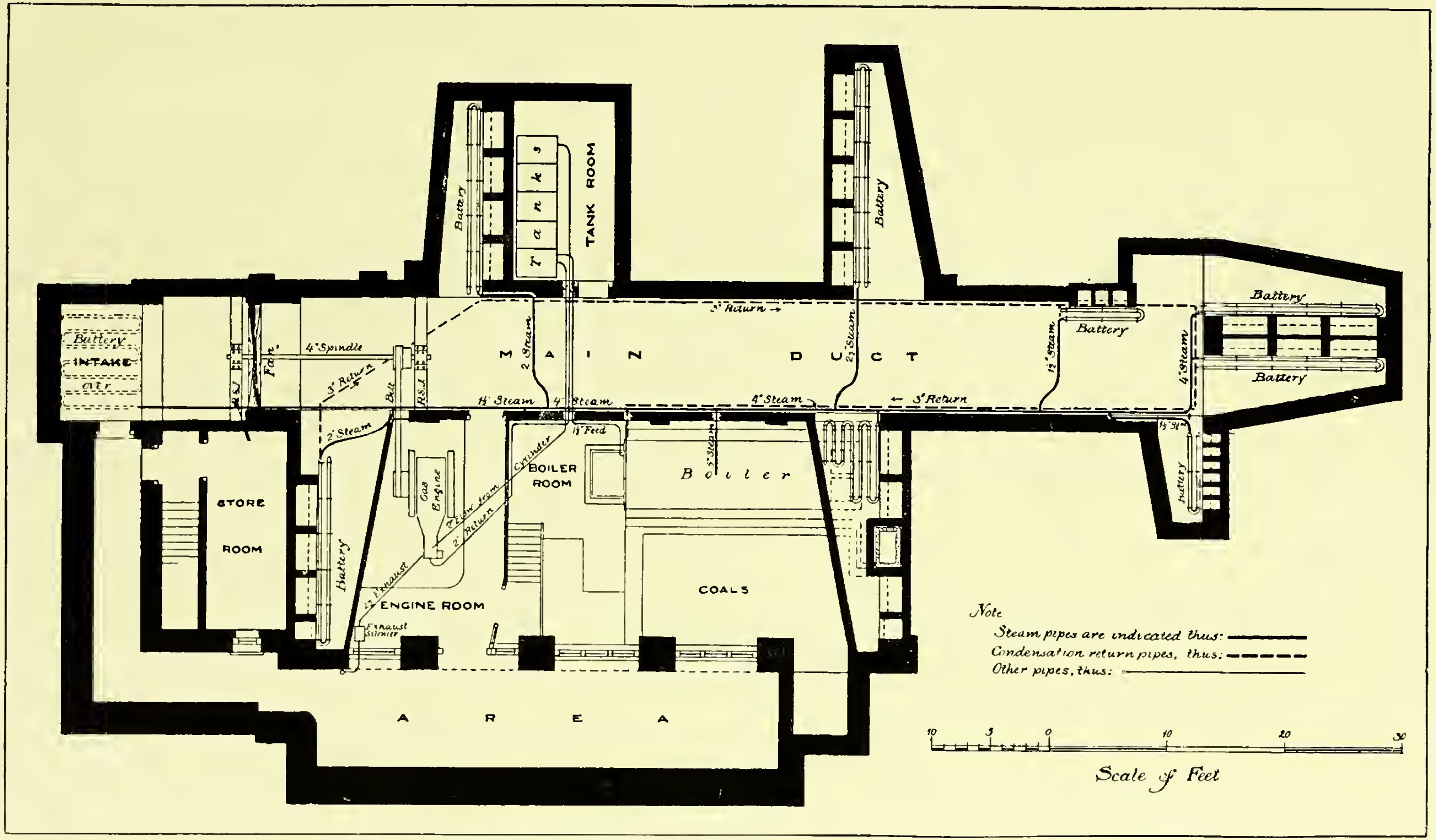


Fig. 439.—Vertical Sliding Damper

These **dampers**, like the horizontal ones regulating the supply, should be well painted, or other means adopted to protect them from the action of the water when cleansing the ducts and flues. It will prove convenient if they are lettered or figured, or given some distinguishing marks to enable the attendant to see at a glance to which room any flue leads.

Every battery, pipe, and other metal work situated in the ducts and liable to corrosion and rust should be **thoroughly galvanized.** The additional cost is very little, whilst such a protection to the metal enables the attendant to play his hose over the whole of the apparatus coming into contact with the air supply without causing its exposed surfaces to rust. By this simple expedient the pipes and batteries can be kept free from rust and also from dust, which, despite the filtering screen, will find its way into the ducts.

It is advisable to place **a small battery just outside the screen,** in order to keep the water from freezing in the winter. There are only one or two days in the year on which it will be necessary to turn the steam into the outside battery, but nevertheless it is as well to provide against



PLAN SHOWING STEAM-HEATING APPARATUS, &c.

eventualities of this sort. Such a coil is shown in fig. 435 and Plate XXIV.

As the batteries are all placed in the basement, and there are therefore no long risers, **the circulating system** may sometimes be installed on the one-pipe principle, in which the steam circulates through a main which carries the condensation with the steam, performing the whole circuit above the water line of the boiler. Such is the system shown in Plate XXVIII, in which the boiler is at a lower level than the ducts; but such an arrangement is not always possible, in which case the two-pipe system must be employed, and in a great many instances it is necessary to run the condensation water from the wet return into a receiver and to provide an automatic feed pump to convey it back to the boiler.

No pipe should be permitted to cross the duct at such a height as to obstruct the passage. If the course of a pipe necessitates its crossing the duct, it should be run under the floor; and if a main, it would of course be necessary to take the return still lower, and get a drip pipe into it from this part of the main in order to rid the dip of the condensation water which would otherwise lodge there.

The size of the boiler and the number and lengths of the members of the batteries will, of course, depend upon the maximum temperature required, the proposed rate of air change, and generally the amount of work required of the heating apparatus. Given a sufficiently large and effective boiler, together with the requisite radiating surface to the batteries, and there is practically no limit to the degree to which the temperature of the air can be raised (within reason); but assuming that a heating apparatus is installed without any undue extravagance in these particulars, there should be no difficulty in maintaining a temperature of 62° F. in the rooms treated when the thermometer shows an external temperature of 10° below freezing-point. While it is unwise to go to the expense of an apparatus unnecessarily above what is required, it is best to err on the side of sufficiency

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CHAPTER VIII

AIR CHANGE

Air Change.—The supply of dilute oxygen and the expulsion of carbon dioxide, organic matter, and all the waste products of respiration and perspiration is the end towards which all the apparatus employed in a system of ventilation is aimed. In a system of plenum ventilation the supply of air and its subsequent expulsion are not left to chance, but in the case of each apartment concerned form a problem or (more strictly) a series of problems in pneumo-dynamics.

A moving body has three attributes to be dealt with in relation to this science, namely, its mass, its velocity, and its direction.

Mass is density × volume.

Velocity is distance passed through ÷ time. When two or more forces

acting upon the mass tend to produce a corresponding number of velocities, the resultant velocity may be ascertained and represented by a finite straight line in the usual way employed in the calculation of static forces.

Direction may be represented in like manner as the direction of the force or of the resultant of the component velocities.

In abstract dynamics, as relating to solid bodies, the mass is definite and constant; but as applied to the question before us, though in a purely theoretical and scientific computation of forces it would be taken as constant, being the volume and density of the air actuated at a given moment, yet for practical consideration we must also take the bulk as indefinite, in the sense of its being *the atmosphere* passing through the building and estimated in conjunction with its velocity. Thus, we may confine our attention to a certain constant and definite bulk of air as though it were a solid body, and say it is propelled S ft. in T seconds, or that its velocity is $\frac{S}{T}$, or, if the time be the unit, then S ft. per second. We must also be ready to deal with the air in front of and behind it, and to say that if A represents the area of the inlet to a room, and the velocity be S ft. per second, then we are supplying the room with air at the rate of AS cu. ft. per second (the one dimension of space represented in the velocity per second, multiplied into the two dimensions of space in the area, resulting in the three-dimension or cubic measurement). Thus, velocity is regarded in two ways: (1) in its strictly theoretical sense of abstract motion represented by lineal feet per second, and (2) to express the amount of air change represented by cubic feet per second (or in terms of any other units).

Since the air change is equal to the velocity multiplied by the area of the inlet opening, it is of course affected by any variation in the value of either; but if the value of the one be altered and the value of the other changed in an inverse ratio, the amount of air change will remain constant. Having decided on the necessary amount of air change, it will therefore be necessary to consider its components separately, namely, the velocity and the sectional area of the injected column of air. As the velocity directly affects the comfort and convenience of the occupants, and also the effective distribution of the air, it demands first consideration. Having decided this, the size of the inlet opening follows in natural course:—

$$\text{Air change} = \text{area of opening} \times \text{velocity}.$$

$$\therefore \text{Area of opening} = \frac{\text{Air change}}{\text{Velocity}}.$$

The velocity will be governed by the **size and power of the fan**, which must be capable of supplying the air required for the whole building; and this total propelling power, after allowing for loss by resistance and escape, will be the basis of calculation for the required motive power.

The next consideration is **the direction of the air** in the apartment, which embraces the subject of the positions of inlet and outlet and the general course of the atmospheric movement. This will influence the positions of the respective flues. The positions allocated will in turn govern the run of the ducts.

In actual practice, however, it will be impossible to treat the various problems quite separately. It has already been shown how inseparably allied are mass (or as it is more generally expressed when neglecting the question of density, "volume") and velocity. Similarly velocity affects direction, so that the one must be regarded in conjunction with the other; and the question of temperature influences everything in a measure. It is necessary in everything connected with propulsion ventilation to provide for a maximum requirement, as both air change and temperature are modified only by reduction.

No fixed rule can be laid down for **the air change of buildings**, for not only do the rooms vary in size and shape indefinitely but also in the number of persons they are intended to accommodate, and the purposes for which they are to be used. A frequent practice is to provide a change at so many cubic feet per head per unit of time, the supply of course depending upon the amount of vitiation. It has been found by experiment that air which contains no more than ·06 per cent of CO_2 is perfectly fit for breathing. As the air in its so-called pure state may be said to contain ·04 per cent of carbon dioxide, this is tantamount to saying that when the air has been vitiated to the extent of charging it with an additional ·02 per cent it may still be said to be sufficiently pure. But when more than that amount of carbonic acid has been added through the chemical process of breathing, the presence of effete organic matter soon becomes perceptible to the senses It has therefore become somewhat general to regard ·06 per cent CO_2 as indicating the limit of purity; and if this be accepted, then without any systematic removal of the polluted air as soon as formed, but allowing for its total diffusion,[1] it will be sufficient to expel enough of the whole mixture by the introduction (by diffusion) of pure air (containing ·04 per cent of CO_2) in such quantities as to retain the balance at a point not exceeding ·06 per cent. This is known as ventilation by dilution.

The carbonic acid coming from the lungs may be taken as the basis of calculation. The rate of respiration is from 15 to 21 per minute, and each respiration represents about 20 cu. in. Assuming the apartment to be one where the occupants are not subject to exertion, the average number of respirations will be (say) 17 per minute.

Then the respirations = 17 × 20 = 340 cu. in. per minute,

$$\text{that is, } \frac{340 \times 60}{1728} = 11{\cdot}8 \text{ cu. ft. per hour.}$$

As only about $\frac{1}{30}$ of this total is CO_2,

$$CO_2 = \frac{11{\cdot}8}{30} = {\cdot}4 \text{ cu. ft. per hour (about).}$$

But ·02 per cent additional CO_2 is allowable, and the volume of air required to dilute to that extent the additional ·4 cu. ft. of CO_2 will be

$$\frac{100 \times {\cdot}4}{{\cdot}02} = 2000 \text{ cu. ft. per hour.}$$

[1] This method of representing the standard of ventilation belongs more to the natural mode than to mechanical ventilation.

This is a very low rate for ventilation by simple dilution, as will be seen by the slow respiration calculated upon. Some scientists place the average much higher, involving a generation of CO_2 amounting to ·6 cu. ft. per hour, and necessitating a dilution attainable by the impulsion of 3000 cu. ft. per hour per head when the occupants are in repose, while adding 25 or 50 per cent to this amount in the case of hospitals. Others again place it lower by adopting a lower standard of purity. But in a properly-designed system of mechanical propulsion, the vitiated air is expelled before diffusion takes place to any appreciable extent, and consequently a supply of 2000 cu. ft. per head is generally ample to keep the purity of the air on the breathing line not only up to but above the standard represented by ·06 per cent of CO_2.

This rate of supply is not applicable to all cases, as, for instance, a **hospital for infectious diseases**, where a greater air supply is necessary owing to the special sanitary conditions, and where also, as the cubic air space would be about 2000 ft. per bed, a delivery of 2000 cu. ft. per head per hour would involve but one change of air per hour. This slow rate would allow the vitiated air to diffuse to such an extent as to reduce the ventilation to a mere system of dilution, and would provide insufficient heat during the winter months. It will be seen from this instance that it is necessary also to consider air change in relation to the time taken in completely changing the air in an apartment, or, as it is more generally expressed, the number of changes per hour. This is a far more general method of measuring air change, and one more peculiarly applicable to plenum ventilation, though the amount of supply and expulsion should in all cases be carefully considered from all standpoints.

The general ward of an ordinary hospital usually has slightly less space than an infectious hospital, (say) from 1200 to 1500 cu. ft. per bed. It is particularly essential in this case that no annoyance to the patient should be caused by rapidity of current; at the same time a generous air change is necessary on account of the extent of the air space operated upon, for the reasons already stated.

Another consideration pointing to the necessity of a plentiful supply is **the question of heating**. An insufficient change would make it difficult to keep up the necessary temperature in winter, and in summer, with the sun streaming in through an abnormally large glass area provided for the special purpose of its admittance, the ward would become overheated were the air retained too long. We must therefore provide a large supply affording a complete change of air (say) 10 times per hour in the summer. To avoid any unnecessary velocity in the air currents, a movement sufficient only to give thorough circulation must be employed. This points to a large volume without any high velocity of delivery. The comparatively narrow proportions of a ward render this possible.

In the instance of an **isolation ward**, which is a room provided for the observation and treatment of special cases, an even higher maximum rate of change may well be provided for, in order to give the physician more opportunity of regulation both of air supply and temperature. Probably in no other case is perfect ventilation such a boon as in this. On account

of its reliability, and the perfect control which characterizes the employment of mechanical ventilation, the physician may treat one patient with baths of cold air in the summer and another may have the temperature raised to practically any degree in the winter, without loss of ventilation, provided only that ample battery surface is provided for this special effect.

Quite another set of conditions obtain in the ventilation of a **school class room.** Here the occupants are supposed to be engaged in active bodily exertion, for brain work is literally bodily exertion in a degree not generally appreciated. A very large amount of waste and repair are necessary to mental exertion, and consequently a plentiful supply of air is required to promote vitality. This is no mere matter of theory, but can be demonstrated by chemical analysis of the vitiated air, and it has been proved beyond doubt that, when other things are equal, a higher average of successes is obtained by the scholars who work under conditions of a good air supply than by those who are less fortunately situated.

Another fact that must not be lost sight of is, that the children sit together in a room of such dimensions as to afford but a small amount of either floor space or air space per scholar.[1] Apart from the question of economy, this is necessary to effective class teaching This condition is seriously aggravated in some schools in poor districts, where the majority of the scholars are not particular as to cleanliness either of their persons or of their clothing. A visit to such a school, where the ventilation is defective —particularly on a wet day,—is sufficient to convince the most sceptical of the importance of this consideration. Take as an example a class room such as one of those shown in plan in Plate XXVI. Here we have a room 24 ft. 8 in. × 24 ft. 6 in., which is to contain 60 scholars sitting close together in pairs at dual desks. If the room is 14 ft. in height, the cubical contents will be less than 8500 ft. The children, from the nature of their occupation, require an ample supply of oxygen, and on hygienic grounds it would be well to bathe them with a good flush of air. In other words, the velocity should be as high as can safely be permitted without the risk of inconvenience. If the supply be placed at 2000 cu. ft. per head per hour (which would be fairly liberal for a child), the total supply must be ($2000 \times 60 =$) 120,000 cu. ft. per hour. This would represent an air change of $\frac{120,000}{8500}$ = about 14 times per hour, which is a rapid rate but not too fast in the circumstances, at least for the summer months.

If, instead of a class-room, a **dormitory** were the apartment to be ventilated, a much lower rate of change would suffice. And if sufficient air change could be attained, the supply per head might also be reduced, for in sleep fewer bodily organs are in operation than at any other time, and consequently there is a less demand for oxygen, and respiration becomes lower to the extent of about 25 per cent. On the other hand, with the decrease of vitality there is a corresponding decrease in the amount of heat generated, so that sufficient air change will be necessary to sustain a proper

[1] The children necessarily occupy but about half this limited floor space, and the teacher and the school apparatus the remainder.

temperature, which apart from any other consideration is a healthier mode of keeping the person warm than by shutting in the natural animal heat by such a supply of bed clothing as to interfere with proper perspiration.

From these examples it will be seen how the particular circumstances governing the question of air supply must be duly weighed before deciding on the volume per head or **the rate of change**. A general idea of the latter may be conveyed by the following table, which of course is subject to variation as the case may demand:—

	Number of Changes per Hour.	
	Winter.	Summer.
Hospitals.		
Out-Patients' Department	9	12
Wards	7	10
Day Rooms	6	9
Operating Theatre	5	8
Lecture Rooms	5	8
Administrative Rooms	5	8
Corridors	4	6
Lavatories, Water Closets, &c.	4	6
Schools.		
Class Rooms	10	14
Halls (Ground Floor only)	10	14
Halls (above Ground Floor)	8	12
Science and Art and Upper Standard Rooms, &c.	7	10
Teachers' Rooms	5	8
Corridors	4	6
Cloak Rooms and Lavatories, &c.	4	6
Public Offices.		
Council Chamber	7	10
Offices	7	10
Committee Rooms	6	9
Halls	6	9
Corridors	4	6
Lavatories, Water Closets, &c.	4	6

It is usual to allow a slower change in the winter than in summer. Generally speaking, people object more readily to draught or anything in the way of perceptible atmospheric movement in the winter than in the summer. It is for that reason that it has previously been suggested that the propeller should be fitted with two pulleys, in order by the double gearing to enable the attendant to make the necessary alteration in the supply without reducing the speed of the motor.

The question of the absolute velocity of the air—that is to say, the lineal speed with which the air should move in entering the room—is so much involved with the direction of its motion that it will be most convenient to consider first the positions and formation of **the inlet and outlet openings**, and the influence of temperature on the path of the movement. The general distribution of the apertures may be arranged in four ways, namely: with both openings above the breathing line, with both openings below the breathing line, with the inlet below and the outlet

above, and, lastly, with the inlet above the breathing line and the outlet below.

All four of these dispositions have been tried at various times with varying results. In the case where both openings are above the breathing line the circulation moves mainly in the plane of the openings, leaving the vitiated air in the lower portion of the room practically undisturbed.

The portion of the room most requiring air change receives a better effect when both openings are below the line; but in such a case the upper part of the room remains unventilated or nearly so; and this part, though in other circumstances less likely than the lower part to contain a large percentage of vitiated air, soon becomes seriously contaminated by diffusion from the used air which is constantly circulating beneath it. Another objection to the impulsion of the air on the level with the occupants of the room is the impossibility of avoiding draughts, unless the supply is admitted at such low velocity that its movement is insufficient to ensure a thorough circulation over even that part of the room which it is calculated to ventilate.

The same objection applies to the system of upward ventilation, in which the air is admitted below the line and ejected above it. Besides this, the upward current bears with it the vitiated air past the breathing line, to be breathed again in passing, together with the dust from the floor borne in by the boots of the occupants. Apart from these considerations, such a disposition of inlet and outlet can be made to circulate the air throughout the room, if the inlet is placed on the floor level and the outlet at a sufficient height, but the objections stated detract seriously from the general efficiency of the system.

The downward method of ventilation—wherein the air is introduced above the breathing line and the vitiated expelled below that plane—is more thorough in its operation than any of the others, and is not subject to their imperfections. It is still regarded with a certain amount of disfavour by some, owing to the idea that a downward motion is contrary to the tendency of the vitiated air to rise. The fallacy of this idea has already been pointed out. That the expired air rises a short distance above the breathing line under conditions favourable to such a motion is perfectly true, but the movement would have to be more rapid than it is if an effective downward ventilation were insufficient to neutralize it. And not only does the downward system hasten the expired gases to their natural position, but it effectually prevents the excretion from the skin rising to the breathing line. A glance at fig. 433 will be sufficient to explain this effect.

The figure also represents a quantity of vitiated air, the result of the **combustion of gas**, just below the ceiling. This must not be neglected where gas is used as a means of artificial lighting, and it will be necessary to form an opening of suitable dimensions at the ceiling level, connected with the outlet flue, or where a false ceiling is used an opening may be made in the ceiling, and a horizontal flue formed between the ceiling and the floor to convey the fumes to the outlet flue. The shape and construction of the horizontal flue will, of course, depend upon the construction of the floor containing it. Neither the flue nor the opening need be very large, as the

upward tendency of the heated gases is so great that they will readily take advantage of the means of egress offered. The opening should be fitted with a hinged flap, supplied with suitable gearing, which can be closed when the gas is not alight. This, like the flue and the opening itself, must be constructed and fitted in accordance with circumstances.

The best position for the inlet opening is at a height above the floor about three-fifths of the total height of the room. If vacant apertures of the dimensions required are considered unsightly, they may be filled with wire or light ornamental metal grids (fig. 440). These must be easily detachable to facilitate cleaning, and it should be remembered that whatever is placed in the opening forms an obstruction to the passage of the air, and must be allowed for in the calculation.

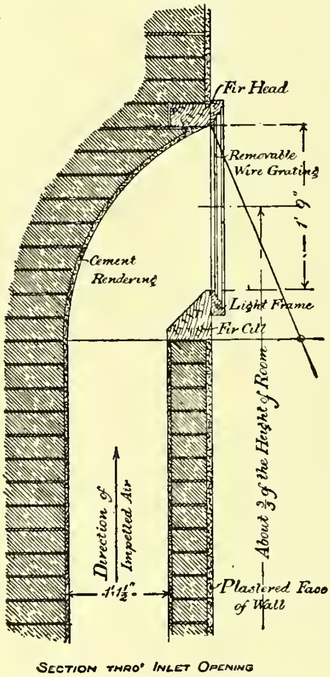

Fig. 440.—Detail of Inlet Flue

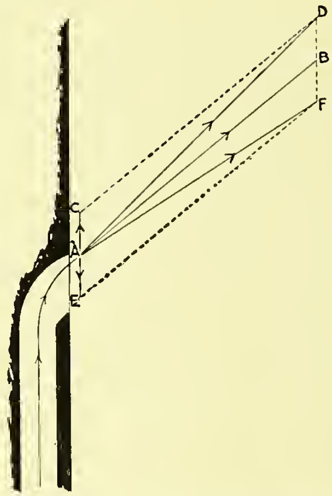

Fig. 441.—Inlet Currents affected by Temperature

The back of the inlet flue should be brought forward to the top of the opening to form an easy bend (fig. 440), as this formation offers the least resistance to the air and allows it to retain much of its upward velocity when projected into the room, as shown by the line A B (fig. 441). This initial direction will be influenced to some degree by the temperature of the incoming air. In winter, when the supply is warmed, its inherent heat will add to its motion a directly upward velocity (A C), due to the buoyancy of the expanded air, giving an initial resultant velocity A D. In summer, the velocity due to temperature will be the reverse, as indicated by A E, giving a resultant A F.

The velocities due to temperature are not very great, since the temperature of the room is never very different from that of the incoming air if a fairly rapid air change is taking place. In winter, when draughts or perceptible movements are most objectionable, the line of direction is elevated, and

therefore kept farther from the heads of the occupants, while the motion is slightly accelerated (as demonstrated by the excess of A D over A B), and it is only in summer (when such objections are less likely to arise) that it is depressed, and then the tendency is to reduce the rapidity of the motion (compare A F with A B).

The actual velocity with which the air is propelled into the room should never be so high as to cause a draught, but at the same time it should be sufficient to create a thorough circulation through the room. In the case of a hall or other large apartment, where the inlets would be at a considerable height above the breathing line, a high velocity might be applied without any ill results; in fact it should be, to effect a proper movement through so great a space. But in a room of such dimensions as the class room already instanced, it would be unwise to admit the supply at a greater velocity than about 6 ft. per second, even in summer. If air at such a rate of motion came into contact with the person, it would occasion considerable discomfort, though it were of a normal temperature. If the incoming air were either very warm or very cold, the annoyance would be proportionately increased, notwithstanding the surrounding air being of a similar temperature. Dr. Reid gives the following as the results of his experiments:—"Air at 55° F. to 60° F., travelling at 1½ ft. per second, is not perceptible; at 2 to 2½ ft. it is imperceptible to some persons; at 3 ft. it is perceptible to most; while at 3½ ft. it is perceptible to all, and anything above this causes a feeling of draught. If the air be warmed to 70° F., a greater velocity is not perceived, but if the temperature be as high as 90° F. it again becomes more perceptible; this also happens if it be lowered, say to 40° F."

It might appear that a delivery at 6 ft. per second would not be permissible even at a reasonable temperature; but in reality this velocity is so retarded by the reaction of the air in the room that, provided the inlet be judiciously placed, no ill results would ensue.[1] On the other hand, for the fresh air to search out the remote corners of the room, it is generally necessary to maintain a velocity of at least 4 ft. a second even in winter.

Area of Inlet.—The class room under consideration requires, for reasons already stated, a good circulation to maintain healthy conditions, and the air should therefore be given a velocity of 6 ft. per second. This will decide the effective area of the inlet opening. The term "effective area" is used, as the actual area is subject to deductions. In the first place the air, moving rapidly up the flue, passes the lower part of the inlet opening for a space of 4 or 5 in. before its velocity attains the horizontal component which projects it through the aperture. A glance at fig. 440 will make this clear. Again, if a wire grating is fixed, the total area of the metal must also be deducted.

Since the total air change = A S (where A = the area of the shaft of air and S = the velocity), and the air change as decided = 14 changes per hour of 8500 cu. ft. = 119,000 cu. ft. per hour, and the velocity = 6 ft.

[1] The author has found, by experiment, that a velocity of 6 ft. per second at the inlet grating becomes reduced to about 3½ ft. per second when it has travelled a distance of 2 ft.; whilst at a distance of 4 ft. from the opening the anemometer registers only 2 ft. per second.

per second $= (6 \times 60 \times 60) = 21{,}600$ ft. per hour, therefore 119,000 ft. $=$ 21,600 A, and A $= \dfrac{119{,}000}{21{,}000} = 5\tfrac{2}{3}$ ft. If the opening is to be covered with a light grid, covering (say) 10 per cent of the opening, then about 11 per cent (*i.e.* 10 per cent + 10 per cent of 10 per cent) must be added to allow for the grid and for additional friction. This brings the required area to about 6·29 sq. ft.

Supposing the inlet opening to be 4 ft. 6 in. long (of course it is advisable to adhere to brick dimensions as far as possible), then the height of the opening will be $\dfrac{6{\cdot}29}{4{\cdot}5} = 1$ ft. 5 in. (about). If we now add (say) 4 in. for the ineffective space at the bottom of the opening, the total height of the aperture becomes 1 ft. 9 in.

It is found advisable to make the velocity of the air in **the supply flue** as nearly as possible equal to that of delivery. It is also expedient to make the length of the flue (on plan) equal to that of the opening. (See the plan in Plate XXVI and the section in Plate XXVII.)

It is obvious that, if the rate of delivery and the velocity in the flue are to be equal, the area of the flue must be equal to the effective area of the inlet opening. This has already been found to be about $5\tfrac{2}{3}$ sq. ft. Then, since the length of the flue on plan is to be equal to that of the opening, namely, 4 ft. 6 in., it leaves but one dimension to be ascertained—that is, the width of the flue.

The required width $= \dfrac{\text{area}}{\text{length}} = \dfrac{5{\cdot}66}{4{\cdot}5} = 15$ in. (approximately).

The total supply for all the rooms, halls, corridors, and cloak rooms will represent, in calculation, the supply required to be propelled by the fan, and proper allowance must also be made for wastage.

The dimensions of the ducts, also, will depend upon the amount of air they have to pass; but it would be a great mistake to make the areas of the ducts equal to the total areas of the flues which they supply. The best results are obtained when the sectional area of the main duct is several times the area of the propeller. By this means a reservoir of compressed air is provided, which greatly adds to the steadiness of the supply.

Having arranged the details of the supply, it will now be necessary to consider the means of getting rid of the vitiated air. The position of **the outlet opening** must be such as to afford easy egress to the air as soon as perfect circulation has been completed by it, and not before. This aperture must therefore be in the same wall as the inlet opening, in order that the air, after it is impelled from the inlet, may complete practically a whole circle, impinging on the opposite wall, and being pushed down to the floor by the pressure of the air behind it. Having lost its initial velocity by this time, it moves, under the pressure, along the line of least resistance, to the outlet opening, as vitiated air. The outlet should be on the floor level, and should be at least half as large again as the inlet, in order not to resist the movement of the air to too great an extent. Another reason for making the outlets of a good size is that if the outlet were (say) the same size as the inlet, the air would necessarily pass out of the room at the same velocity

(neglecting wastage) as it entered; but by increasing the area the necessary velocity of the expelled air is proportionately reduced, and so maintains a better circulation in the room.

Furthermore, the effective area of the large opening is not reduced in such proportion by the accidental situation of persons or objects immediately in front of it. But, at the same time, the placing of anything in a permanent position immediately in front of and close to the outlet should obviously be carefully avoided, as anything of the sort naturally interferes with the system of air change. The aperture may or may not be covered with wire netting or a light grid as in the case of the inlet, but in the same way the impediment must be allowed for in the size of the opening. As such a contrivance is seldom necessary, either for its usefulness or for appearance, it is usually dispensed with.

The direction of the movement is analogous to that illustrated in fig. 434, with the portion from A to B omitted, except that the motive force is supplied by mechanical means instead of by heat expansion of the air. It will be seen that it would be useless to place the outlet in any other position—in the opposite wall, for instance; for in that case the air would complete only a part of the circulation, leaving the floor space, where it is most required, undisturbed. Again, if the outlet came immediately under the inlet, the air would indeed complete a circulation through the section of the room; but considered in relation to the length of the apartment,[1] the circulation would be confined to a vertical plane extending across the room in a line with the openings. It is true that the air supply begins to spread out as soon as it leaves the inlet, and continues to do so until it begins to be pressed towards the outlet, but this action would not be sufficient to ensure a thorough circulation through the length of the room.

The ideal relative positions of inlet and outlet are therefore where the former is near one end of the room at the prescribed height from the floor, and the latter near the other end of the same wall, and on the floor level. This gives to the mean line of direction the form of circulation both latitudinally and longitudinally—that is to say, broadly, the course of the air is in the shape of nearly one turn of an elongated spiral.

The resistance to the egress of the air is contributed to by the weight of **the column of vitiated air** in the outlet flue, where, in cold weather, it rapidly cools. The air pressure in the apartment must therefore be sufficient to raise this weight. The gathering of the outlet flues into a trunk, and the introduction of the "extract fan" before mentioned, are means that may be employed with advantage in relieving the resistance to some degree; but this must be done with great care, for it must be remembered that it is due to resistance that the air is retarded at the inlet, and is compelled to spread out over its prescribed path. Were this opposition reduced to any great extent, the air would move from the inlet to the outlet, along the line of least resistance, without performing its work of circulation.

In large apartments, such as the hall shown in plan in Plate XXVI (which is still further enlarged by the opening of the folding partition),

[1] In speaking of the "length" of the room, it is assumed that the fresh air is projected across the width.

it becomes necessary to introduce more than one pair of openings; but this is merely a complex problem based on the principles already explained, and requiring thought and experience for its solution. In no case can the absolute position of the openings be indicated without regard to surrounding circumstances. In this case a separate circulation must be provided for the class room and another for the hall, both of which must be complete in themselves; and when the partition is opened, they must work in harmony as one apartment. All such things must be duly considered in arriving at the number and positions of the various openings.

CHAPTER IX

COST AND PROFESSIONAL PRACTICE

One of the first questions to present itself to the architect who contemplates the adoption of the plenum system of heating and ventilation is "**What will it cost?**" If this system is a thing outside his past experience, the question may appear somewhat difficult to answer even approximately. It will be of assistance, therefore, to present some comparison between the cost of heating by propulsion and that of hot water and of open fires. Such a comparison must naturally be somewhat unfavourable to propulsion, for in heating by hot water, or by fires, the heating alone is paid for, and the natural ventilation, disadvantageous though it may be in other respects, is given gratis; whilst with the plenum system the cost covers the provision of both heating and ventilation.

The question is a twofold one. It is not sufficient to know **the initial cost**, but also that of maintenance. The following statement, taken (with some alterations) from the author's work on *The Plenum or Propulsion System of Heating and Ventilation*, shows the comparative cost (calculated at London prices) of heating a manufactory, workshop, or school to accommodate 1200 workpeople or scholars. The cost of the propulsion system, besides providing for the necessary heating, includes the supply of 2000 cu. ft. of air per hour for each person, or a total of 2,400,000 cu. ft. per hour.

To install a propulsion system capable of supplying this quantity of air, and providing an isolated chamber for the mechanical apparatus, including the formation of ducts, flues, inlets, extracts, and all other sundry builders' work, would cost about £2500. To this sum must be added £1500 for the provision of boilers, pumps, batteries, propellers, gas engines, or electric motor, and other sundry mechanical apparatus, making a total initial outlay of about £4000.

To provide a similar building with a hot-water apparatus, the cost would be about £1085 for the basement, furnace flue, channels, and builders' work, and the sum of about £915 for the hot-water apparatus, or a total initial outlay of about £2000.

For a similar structure with open fireplaces, the cost of providing

coal cellar, chimney breasts, flues, chimney stacks (with architectural finishings), and stoves and mantels, &c., would be about £1800.

The propulsion system will, therefore, in the first instance, cost about £2000 more than a hot-water apparatus, and about £2200 more than open fireplaces.

Maintenance (Propulsion Installation).—Every time the fire is relighted in order to get up steam during the winter months, it would take about three hours and require about $3\frac{1}{2}$ cwt. of coal at 24*s.* per ton, value 4*s.* 2*d.*; but as the fires are banked up every night, and drawn usually at each week-end only, this item would amount (for the thirty weeks from October to April inclusive) to £6, 5*s.* per annum.

The cost of maintenance per hour of occupation would be as follows:—

	s.	*d.*
Coal, 1 cwt. at 24*s.* per ton, ...	1	2
Gas engine, 200 ft. of gas at 2*s.* 3*d.* per 1000, ...	0	$5\frac{1}{2}$
Water for filtering and humidifying, 50 gal. at 10*d.* per 1000 gal.,	0	$0\frac{1}{2}$
Total per hour, ...	1	8

But if wages are included for mechanic, (say) 10*d.* per hour, the total cost would be 2*s.* 6*d.* per hour.

During the summer months, however, only the propellers and humidifiers would be in use, the cost of which would be 6*d.* per hour for gas and water.

Now, estimating that the heating will be required for thirty weeks, from October to April in each year (both months inclusive), the minimum cost of working the apparatus per annum, for (say) ten hours per day and four hours on Saturdays for three hundred working days, would be, at London rates, as follows:—

	£	*s.*	*d.*
Initial cost of getting up steam, thirty occasions at 4*s.* 2*d.*, ...	6	5	0
Coal, 54 cwt. per week for 30 weeks = 81 tons at 24*s.*, ...	97	4	0
Gas engine, 54 hours per week for (say) 43 weeks = 2322 hours at 200 ft. of gas per hour = 464,000 ft. at 2*s.* 3*d.*,...	52	4	0
Water, 2322 hours at 50 gal. per hour = 116,000 gal. at 10*d.*,	4	17	0
Oil, waste, repackings, repairs, and renewals, ...	20	0	0
	180	10	0
[1] Add wages of skilled mechanic, 52 weeks at (say) 45*s.*, ...	117	0	0
Total cost of maintenance per annum, ...	297	10	0

Hot-water Apparatus.

	£	*s.*	*d.*
Initial cost of heating water, 30 occasions at 4*s.* 2*d.*, ...	6	5	0
Coal, $\frac{3}{4}$ cwt. per hour = 41 cwt. per week for 30 weeks = $61\frac{1}{2}$ tons at 24*s.*, ...	73	16	0
Add for water, repacking, cleaning boiler periodically, renewals, &c., ...	14	0	0
	94	1	0
Add wages for unskilled attendant, 52 weeks at (say) 35*s.*, ...	91	0	0
Total cost of maintenance per annum, ...	185	1	0

[1] The mechanic would not necessarily devote the whole of his time to the working of the apparatus; but this would apply to the comparative cases also, as other odd jobs in connection with the building would be found to fill up any spare time which the mechanic might have, whether the building were heated by plenum system, hot water, or open fireplaces.

Open Fireplaces.

	£	s.	d.
36 fireplaces consuming $\frac{1}{2}$ cwt. of coal for 5 days a week and $\frac{1}{4}$ cwt. on Saturdays = $2\frac{3}{4}$ cwt. per week for each fireplace = 99 cwt. per week for 36 fireplaces and for 30 weeks = $148\frac{1}{2}$ tons at £1, 1*s.* 6*d.*, ...	159	12	9
Cost of lighting 6480 fires (wood, matches, &c.), at $\frac{1}{4}$*d.* each,	6	15	0
Repairs to 36 stoves at 10*s.* each per annum, ...	18	0	0
Renewals of fire irons, &c., 36 fireplaces at 1*s.* 6*d.* each, ...	2	14	0
	187	1	9
Add wages for unskilled attendant, 52 weeks at (say) 35*s.*, ...	91	0	0
Total cost of maintenance per annum, ...	278	1	9

The comparative cost of the three systems, including 6 per cent interest per annum on the initial outlay in combination with the total maintenance per annum, would be as follows:—

	Propulsion.				Hot Water.				Open Fireplaces.		
	£	s.	d.		£	s.	d.		£	s.	d.
Initial outlay, ...	4000	0	0	...	2000	0	0	...	1800	0	0
6 per cent on total initial outlay	240	0	0	...	120	0	0	...	108	0	0
Maintenance per annum ...	297	10	0	...	185	1	0	...	278	1	9
Total cost of maintenance per annum, allowing 6 per cent interest on initial outlay ...	537	10	0	...	305	1	0	...	386	1	9

Probably no architect or engineer would have the temerity to evolve and carry out an entire scheme of plenum ventilation without any previous practical experience. Were he to do so, the odds are greatly in favour of disaster. Neither is the other extreme to be recommended, though unfortunately a common practice, by which the architect accepts a tender from the ventilating engineer, who afterwards contracts to secure results that he himself proposes, in accordance with his own specification, under his own supervision, and to his own satisfaction, afterwards testing the results of the work himself and certifying it as complete and satisfactory, leaving nothing for the architect to do but to build the ducts and flues and other constructional work according to the dimensions and positions decided upon by the engineer. To say the least of it, such a proceeding cannot be called businesslike, not that propulsion engineers are to be trusted less than any other class of contractors, but it does not seem fair to the client to treat the contractor as being above suspicion. The common consequence of work carried out under such conditions is that, at the test, the results guaranteed are just barely attained by the boiler being worked hard by an expert engineer, and the motor run at a pace that bids fair for its early acquaintance with the scrap heap.

One cannot entirely blame the engineer if he performs his work in this manner. He has to produce certain results, and the estimate must be low in the first place by reason of competition, so that everything has to be cut very fine. In reality the client reaps the benefit of this

cutting, and the result is that he has to bear the expense and inconvenience that follow as a natural consequence, just in the same way as he would have done had he not engaged an architect but had appointed a building contractor, at the lowest price, to erect the structure according to his own plans and specification, with the only proviso that the edifice should be habitable at the time of completion, and possibly during a short term of maintenance.

If the architect has not the necessary theoretical knowledge and practical experience to make himself the moving spirit in the matter, he should obtain the **expert advice of an engineer**, who will hold the same relationship with the ventilating contractor as the architect holds with the building contractor. In this way the engineer is no longer treated as an expert entirely alone, but as a collaborator with the architect, both being experts in their respective parts of the work, yet meeting on a common ground in certain particulars.

The architect will have the last word, of course, in his special work, whilst the ventilation engineer will hold the same privilege in his part. Thus the architect will be responsible for the actual constructional work, and will specify generally what is required in the way of air change in the respective rooms, and so on. On the other hand, he would be wise to accept the engineer's requirements as to the precise sizes of the ducts and flues, and although the architect may specify generally the positions of the inlet and outlet openings, it would be accepting an unnecessary responsibility for him to indicate definitely their exact position. In fact, the whole scheme should be a matter of mutual arrangement, the architect making only such stipulations and taking such responsibilities as his knowledge and experience of the subject warrant.

In settling the details of the scheme everything should be calculated for **the maximum requirements**. It is not suggested that the scheme should be unnecessarily large, but it costs so little extra to make a flue half a brick longer, or to provide a motor of one more brake power, if the decision is made before the commencement of the work, whereas, after its completion, such changes can be made only at great expense and inconvenience. If these points are observed, a breakdown during the working of the apparatus will be a highly improbable occurrence; and in cases such as day schools, offices, manufactories, and the like, where the system is worked only in the day time, the minor repairs and renewals may be made during the time of cessation. But in hospitals and asylums, and other buildings where no such opportunities are afforded, it will be necessary to supply the motor and boilers in duplicate, and provision must be made for changing from one to another with as little stoppage as possible in the working.

The architect should confer with the engineer while **the plans** are in their preliminary stage, so that the subject of ventilation and heating may have its share of consideration while the plans are being worked out. By this means a cheaper and more efficient scheme will probably be arrived at than would have been the case had the plans been decided and then a system worked out to fit. When the architect's plans have

assumed definite shape, it will be the duty of the engineer to supply small-scale drawings and details, together with such specification of the work as to make the whole sufficiently concise to form a contract The architect will, of course, see whether these are in accordance with his requirements and sufficiently binding for the purpose.

The engineering contractor should maintain his work in good order for a period of (say) twelve months from completion, and it is a wise course to specify that the engineer shall run the installation during the first month at his own expense, and at the same time shall instruct the attendant whose duty it will afterwards be to take charge of the apparatus.

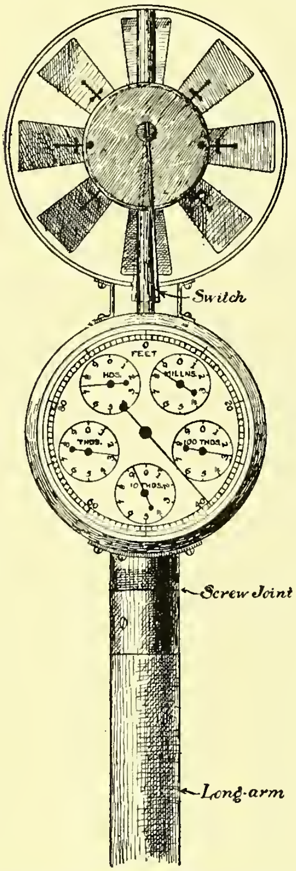

Fig. 442.—Anemometer (half full size)

On the completion of the work it will be the duty of the architect to satisfy himself that the contractor has done all that he guaranteed to do. To do this it will be necessary **to test the temperature and the air change** in the various apartments. Of the test of temperature nothing need be said beyond the fact that it is performed in the ordinary way, the usual mode of measurement being to raise the temperature to a specified degree when the thermometer outside stands at a certain number of degrees lower. It should be remembered that, if the room is occupied by a number of persons, the animal heat given off from their bodies, both by radiation and convection, will have the effect of raising the temperature several degrees.

To ascertain the rate of air change in the apartment it will be necessary first to measure the lineal velocity of the air at the inlet opening, and, given this datum, the total number of cubic feet passed in a given time, the number of cubic feet per head per unit of time, and the number of air changes per hour are matters of arithmetic already illustrated.

To perform this test **an anemometer** (fig. 442) will be required. The propeller-like fan, when set in motion by a current of air, registers the lineal passage of the air on the dials below, the large hand indicating the feet up to one hundred on the outer circle, and the five dials contained therein registering the feet in hundreds, thousands, tens of thousands, and hundreds of thousands. The fan can be released from the rest of the gearing by means of a switch, which allows it to revolve without registering on the dials. The method of use is simple. The instrument is held with its back to the inlet for a certain known length of time, and the number of feet of air passed is noted. Then by simply dividing the number of feet by the length of time, the velocity is reduced to "feet per minute" or "feet per second"

as required. The test is a somewhat delicate operation, and its degree of accuracy will depend very much on the care with which it is performed. If the operator stands with his body directly in front of the opening, he will check the current in some degree, and so render the reading faulty. He should therefore manipulate the anemometer in such a manner as not to impede the inflow of air.

Before making the test it should be ascertained that all the usual conditions obtain as in ordinary working, that the mechanical apparatus is working at a normal speed, and that all windows and doors are properly closed. The circulation should be in operation for at least about the time proposed for a single change, as up to that time the air is not quite so dense as under ordinary working conditions, and consequently does not supply so much resistance to the incoming air. Of course a long test is likely to be more accurate than a shorter one. A second or so lost or gained in a one-minute test would result in a greater error than would be the case in a five-minutes test, and so on.

When all is ready, the operator places the instrument in position with the large indicator set at zero (having noted the positions of the others) and the fan disconnected. He does this to allow it to overcome its inertia and to revolve at full speed before registering. This accomplished, he connects up the fan with the other parts of the mechanism by means of the switch, carefully noting the time by his watch at the same instant. Since the velocity of the air, as it passes the different parts of the inlet, varies from nil at the lowest few inches to a maximum at about the top of the opening, an average must be obtained by moving the anemometer about so as to pass completely over the whole area. A good method is to pass it backwards and forwards in lines which form a series of V's, and crossing and re-crossing the opening diagonally from corner to corner.

Although the anemometer is most delicate in its movement, yet it would be impossible to run without any loss through friction. To balance this, 30 ft. per minute should be added to the computation.

Having discovered the supply passed by all the inlets in the system, the total may be checked by testing the velocity of the air passed by the propeller and calculating the total supply.

Some experts hold that the tests should be made at the outlets rather than as described, thereby deducting any leakage from the total air change. But apart from the inconvenience and difficulty of obtaining an accurate reading on the summit of a pair of steps in cases where provision is made for the expulsion of gas fumes, it seems scarcely a legitimate calculation to exclude from the total the air that leaks through the windows and doors (possibly after being breathed by the occupants), as long as there remains sufficient pressure to ensure the removal of the vitiated air. Moreover, as far as the engineer is concerned, it would certainly be unfair to hold him responsible for defective joinery.

Besides the work of testing the amount of air passed through the system, occasions may sometimes arise when it is necessary to test the quality of the air. To test the air by the sense of smell may seem scarcely scientific enough to mention, but it must be remembered that the standard

of purity is fixed by the perceptibility in that way of the presence of organic matter when the atmosphere contains over ·06 per cent CO_2. It certainly has the advantage of being a test that is readily applied. When the odour is scarcely perceptible, it may be taken that the atmosphere is contaminated only to a slight degree, and that carbon dioxide is present to the extent of something between ·06 and ·08 per cent; beyond that the odour becomes more pronounced, and at ·1 per cent it is objectionable, while at ·12 per cent the presence of effete organic matter becomes decidedly offensive. To perceive accurately the condition of the atmosphere in this way it is necessary to come into the room directly from the fresh air. To enter a room where the air is only slightly vitiated, from a room that is polluted to a greater extent, would induce one to think the atmosphere was sweet and fresh by comparison. The humidity or the dryness of the atmosphere is also likely to render the sense of smell misleading. The odour is more pronounced in damp weather, whilst on a day when the air is very dry the atmosphere may be contaminated to a considerable extent without any perceptible unpleasantness.

To make a **detailed analysis of the air** of an occupied room requires a knowledge of chemistry and an amount of special apparatus that is not possessed by the average architect, and, when necessary, the task should be delegated to an analyst. But to ascertain such details as the degree of humidity of the air, and the percentage of CO_2 contained by it, with sufficient accuracy for ordinary purposes, are operations of comparative simplicity.

The quantity of moisture in the air is found by the use of an instrument called a hygrometer. This apparatus depends for its action upon the absorbent quality of the air being proportionately increased by its dryness, and consequently decreased by its humidity. The instrument consists of two thermometers fixed side by side, one being actuated by the temperature in the ordinary way, whilst the bulb of the other is covered with a wick, the end of which dips into a vessel of water. The water is drawn up the wick by capillary attraction, where it evaporates. As the process of evaporation is productive of a lowering in temperature, the hygrometer registers lower in proportion to the rapidity with which the moisture evaporates, and the moisture evaporates in proportion to the dryness (or otherwise) of the atmosphere; so that, by comparing the readings on the two thermometers, the humidity of the atmosphere is ascertainable.

If the atmosphere is charged with humidity to a suitable extent, that is, containing (say) 65 per cent of the amount of moisture required to attain to saturation, the readings of the two thermometers will show a difference of from 6 to 8 degrees. If the difference is (say) 10 degrees, the air may be considered too dry, whilst with anything less than 4 degrees of difference, the moisture is in excess of the normal. Of course if the air is saturated, evaporation ceases altogether, and consequently both glasses will register alike. Since, however, the temperature also influences the atmospheric powers of evaporation, it will be necessary to take into account the absolute temperature at the time of testing (if it is required to ascertain the exact percentage of moisture), and to refer to the table book.

The percentage of CO_2 may be approximately found in a very simple way. It will be necessary to procure a cylindrical clear-glass bottle fitted with a glass stopper, or (better still) a glass tube sealed at one end and fitted with an air-tight stopper at the other. Cut a strip of paper equal in length to the height of the bottle or tube measured on the inside. From one end of the paper measure off three-fourths of its total length, and bisect the space between the mark and the end of the paper from which it was measured. The paper has now two marks on it. Write against the first marking ·12, and against the second ·06. Bisect the space between the marks and write there ·08. Repeat the process in the space between the ·12 and the ·08, and call it ·1, also between the ·08 and the ·06, calling it ·07. Stick this paper up the side of the bottle, with the end from which the first measurement was taken coinciding with the line of the inside of the bottom. There is now a graduated scale on the bottle marked ·06, ·07, ·08, ·1, and ·12. Fill the bottle with fresh clear lime water, insert the stopper, and the apparatus is ready for use.

On arrival at the place where the test has to be made, see that the room contains a full number of occupants, and ascertain that they have been in the apartment some time, and that everything has been in its normal state meanwhile.

To apply the test, pour off the surplus lime water till it contains just sufficient to reach to the topmost mark. Then fix the stopper securely, and shake the bottle violently, until the air in the bottle has come into contact with the lime water. If after this the lime water appears cloudy, it indicates the presence of ·12 per cent of CO_2, and it will be time to think of improving the ventilation. If, however, the contents of the bottle remain clear, then remove the stopper and gently pour off until the liquid reaches the next mark, and repeat the process as before. If the lime water still remains clear, the test must be repeated at each mark in succession until the carbon dioxide contained in the air in the bottle amalgamates with the lime in the solution. As soon as this occurs, the test is complete, and the mark on the slip will indicate approximately the percentage of CO_2 in the atmosphere of the room.

The reason for completely filling the bottle with lime water in the first place is to exclude the air, as otherwise on arriving at the scene of operation the bottle would be found to be already occupied with the air from another place, and to expel it by means of a pump or bellows would bring about premature chemical changes in the solution.

Lime water is often of use in another way. By placing small quantities in saucers (preferably coloured ones), and distributing them as necessary about an occupied room, the position and direction of the movement of the vitiated air can be readily discovered by the relative time taken to cloud the lime-water in the various positions.

In concluding this chapter, the author would give a word of advice to his fellows, and that is, to **study the systems that are now working.** Test them in every way. Note carefully the good points in each, and see whether they may not be developed and improved to increase their effectiveness. Note, too, with equal care the bad points. There are two ways

of doing a thing, the right and the wrong. Very often, by observing the wrong way, the right may be found.

Finally, **study theory** in all its branches, work always from the fundamental principles which constitute the why and the wherefore; do this thoroughly, but notwithstanding all that may be gained in this way, it is incomplete without the practical knowledge and experience which every student must obtain for himself.

CHAPTER X

WORKING THE PLANT

Success and Failure.—There can be no doubt in the mind of anybody who has had experience in propulsion ventilation, that when a system is a success it is a very great success; but, conversely, when it is a failure it is a great failure. There need be no question of failure as far as the installation itself is concerned, if it has been carefully thought out, and not cut too fine by stinting. That failures do occur is true, but probably from either the lack of experience or the lack of funds.

It often happens, however, that a scheme is properly calculated, the system installed, the building occupied, and heating and ventilation pronounced perfect by all concerned. Everybody is pleased, enthusiastically so—for a month or two. Then someone wants less air or more, and someone else thinks it would be an additional advantage to open a window. This being forbidden, there are shakings of heads and longing looks at the windows, and the conversation turns on the subject of bad air, ending with the unanimous opinion that the old fashion was the better after all. The architect, who has not been near the building since testing the apparatus, goes on living in the happy delusion that everything is satisfactory to everybody, until he receives a request to call and see what can be done to improve the ventilation. Probably he will be met by someone "who knows", and this person will talk of "carbonic acid", "bad air", or, as he will then call it, "plenum air", and other objectionable matters, while the architect is forced to admit that the air is not what it should be. When the gentleman who knows has "shown him over", and explained conclusively meanwhile why propulsion "*can't* work", the poor deluded cause of all their trouble will descend to the basement to see what is wrong. He may make a shrewd guess, and walk directly to a battery if the steam be on, and discover a disagreeable odour arising from it. He will touch the pipes, the floor of the duct, the dampers, the flues, and find—dust, dust everywhere. The attendant will admit that he has not had time during the past few days to use the hose, and if he is pressed as to date, it will be found that the last occasion of a thorough cleaning will be somewhere near the date when the engineer finally handed him the key of the engine room. After a thorough wash down, the air supply will be as fresh and

pure as ever; but it will be long before prejudice is overcome and the occupants satisfied again.

It will be thought that this is all a mere piece of imagination, but in essence the facts are perfectly true. Probably a great many plenum systems which are regarded more or less as failures are all right in themselves, and want but a thorough cleaning to make the air supply perfectly breathable.[1] The difficulty of keeping the air free from dust is usually multiplied tenfold by the negligence of plenum engineers or the cheese-paring wastefulness of their employers; for it is, in truth, wastefulness which saves the slight additional cost that would provide proper protection to the batteries and pipes against rust, and so render it possible to use a hose to remove the dust from their surfaces. The consequence of this false economy is that the dust lodges on the ducts, pipes, and batteries. It would not do to play a hose over the metal if not galvanized or treated in some way, and it is practically impossible to clean by any other means the close masses of tubes forming the batteries, particularly if these pipes are gilled.

There is little doubt in the mind of the author that what is known as "plenum air" is simply air charged with fine dust. The actual material is most elusive. The analyst will witness that the air contains no undue percentage of CO_2, bacteria, or other objectionable matter; the degree of moisture is satisfactory, and yet one has but to breathe the air to know that, in spite of scientific analysis, the atmosphere is unpleasant and lacking in freshness. The air itself is all right, but it is dusty.

Probably some of the dust is drawn through the screen with the swift current of air passing into the building; for though a screen will stop soot and the light large particles in the air, the microscopic atoms which we call dust will pass anything yet invented that will pass air as freely as is necessary in a filtering screen. But a greater proportion finds its way into the building when the apparatus is stopped for the night (in cases where the fan is not kept constantly at work). The doors are shut, but not so closely as to exclude the strong draught caused by the flues, warmed by the day's working, still continuing to circulate air. But the circulation is not strong enough to raise these heavy particles through the perpendicular height of the flues; so they are deposited in the ducts and on the batteries. It would never do to play a hose on the heating apparatus when in steam, and after the day's work is over, and the pipes are cool, he would be indeed a conscientious attendant who would willingly begin work again by flushing down the apparatus with the hose. Thorough and careful supervision must therefore be exercised over the carrying out of this most important work, for cleanliness everywhere is the key to success.

The fans should be set in motion during the sweeping of the rooms. By so doing the downward current of air prevents the dust rising more than a few inches from the floor, and consequently the dust can be removed from the building instead of becoming distributed all over the rooms as a result of the use of the broom.

[1] The author has on many occasions been called in to report on defective systems, and has discovered that they were rendered worse than useless owing entirely to the accumulation of dust.

Hints on Working.—When the apparatus is not continuously at work, it should be started some time before it is required, and the air supply sent into the rooms, &c., at the same speed and temperature as is intended to be supplied during the day. If not started till the rooms are about to be occupied, the atmosphere in the rooms will be stagnant, and the incoming air will be at a different temperature, thus causing draughts.

It is a good practice, however, if a room has been occupied, and then is vacated for a while, to flush the apartment out with cold air, provided there be time remaining to regain the normal conditions before the room is reoccupied.

In cases where parts of the plant have been supplied in duplicate, both should be kept in working order by being run alternately week and week about. If a boiler or a motor is allowed to be idle for any length of time, and there is a breakdown in the working plant, it will probably be discovered that the second apparatus is out of order at the very time that it is needed. Nothing—not even hard work—shortens the life of any mechanism so rapidly as its lying by unused and uncared for. The architect should explain this and all other matters to the attendant in charge of the apparatus; and, to ensure the proper attention to these points, he should provide for continual supervision by someone in authority in the building, whilst an occasional surprise visit from the architect himself will have a distinctly exhilarating effect on the energy of the attendant.

SECTION VIII

SANITARY PLUMBING AND DRAINAGE

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SECTION VIII

SANITARY PLUMBING AND DRAINAGE

CHAPTER I

DRAIN AIR AND TRAP VENTILATION

Shortly described, **the duty of the sanitarian** in relation to buildings is to institute works which will receive the water soiled by domestic use, and the waste matters from the human body—which together constitute sewage,—and convey them from the dwelling house to the sewer or other prepared system, not only with despatch but with freedom from nuisance, and without endangering the health of the individual or the general weal of the community.

Defective Fittings.—Fig. 443 illustrates conditions that are to be found in many houses to-day, if not in the aggregate, at least in one or more particulars. The drain is untrapped from the sewer, and forms a ready medium for disseminating sewer gas through defective joints into the rooms under which it is laid. The sink waste is connected direct to the drain, the sole protection for the users of the sink and scullery being the bell trap let into the sink; the top of the trap is frequently found laid on one side, thereby rendering the fitting entirely useless as a trap. The joints of the soil pipe, which is constructed partly of light iron and partly of zinc, are defective, and the ventilation pipe ends in a position that endangers the purity of the drinking-water supply. In addition, the connection between the soil pipe and the D trap under the water closet is made simply by the insertion of the outgo of the trap into the soil pipe with a putty joint, thus allowing sewer gas to pass into the house.

A moment's consideration of the illustration will serve to convince even those readers who are unacquainted with sanitary problems, of the ease with which the atmosphere of a dwelling house can be contaminated by the foul emanations from sewers and drains, and of the necessity there is for the construction of the drains and sanitary appliances in such a manner as to prevent the emission of offensive odours.

Emanations from Drains and Sewers.—Owing to imperfections which occur during or after their construction, it is no unusual thing to find that sewers and drains have a quantity of matter deposited in them; and even in cases where the most perfect pipes are used, and the greatest possible care taken in the constructional works, deposits will be found,

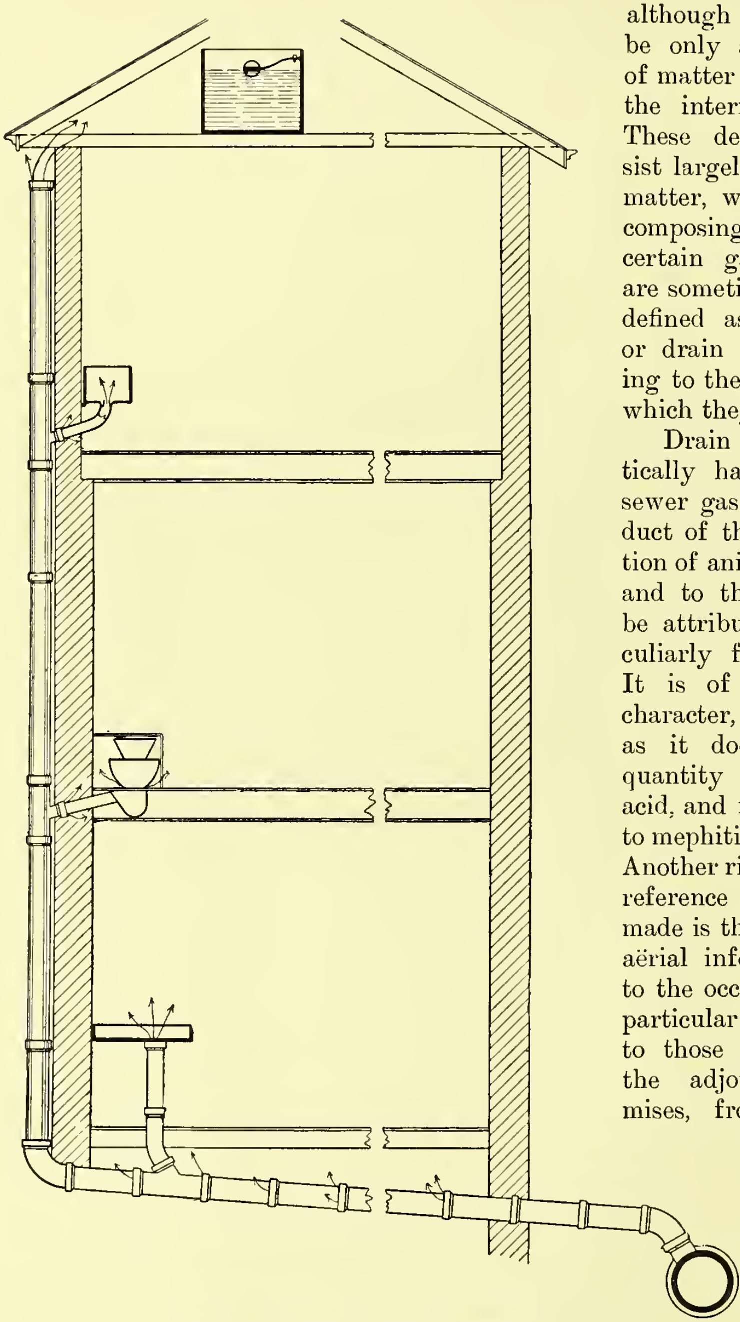


Fig. 443.—Defective Drainage and Plumbing

although they may be only a thin film of matter adhering to the internal surface. These deposits consist largely of animal matter, which in decomposing liberates certain gases, which are sometimes loosely defined as sewer air or drain air, according to the place from which they emanate.

Drain air is practically harmless, but sewer gas is the product of the putrefaction of animal matter, and to this fact can be attributed its peculiarly fœtid smell. It is of a noxious character, containing as it does a large quantity of carbonic acid, and it gives rise to mephitic poisoning. Another risk to which reference must be made is the danger of aërial infection, both to the occupants of a particular house and to those residing in the adjoining premises, from sewage matter infected with the germs of enteric and other zymotic fevers, which are probably disseminated by sewer or drain air.

Traps as Barriers.—It is clear, therefore, that the keeping out of the

dwelling house of foul air from sewers, drains, and waste pipes is an urgent necessity, and it is attained by means of the appliance known as a *trap*, which consists of a receptacle so shaped as to contain a quantity of water, into which dips a portion of the vessel in such a manner as to prevent the passage of air, by forming what is technically described as a *waterseal.* This can best be explained by a reference to the bent tube shown in fig. 444. The portion marked A is the "dip", and the contained water serves the purpose of effectually separating the air in the outlet end B from the air in the inlet end C. In this case the seal is $2\frac{1}{2}$ in. in depth.

Traps may be roughly divided into three classes—

(*a*) *Intercepting traps, i.e.* traps designed for fixing at the lowest end of a drain so as to intercept the flow of air from the sewer.

(*b*) *Disconnecting traps,* fixed at the inlets of all the branch drains, and constructed to receive rainwater, surface drainage, and waste water from sinks, baths, lavatories, &c.

(*c*) *Specially designed traps* for fixing directly under water closets, baths, lavatories, and sinks.

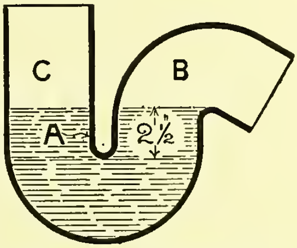


Fig. 444.—Bent Tube forming Trap

Traps a Necessity.—The experience of the last few years has conclusively demonstrated that traps are not fads, but necessities. At the present time it is the fashion in a limited circle—mostly composed of local surveyors—to decry intercepting traps in and out of season. They designate them obstructions, and would doubtless be very glad to see them abolished altogether, owing to the impediment which they impose against the ventilation of the public sewers through the house drains belonging to private owners. Regarding the subject from an opposite standpoint, the sanitarian objects to the house drain being used as the medium of discharge for the noxious gases generated in the sewers, owing to the risk entailed upon the occupants of the house in the event of a defect occurring in the untrapped drain, or in the ventilating pipes or soil pipes directly connected to it.

There is hardly any doubt that the provision of traps in large numbers and of faulty design, during the past ten to twenty years, has accentuated the decomposition of the animal matter deposited in the sewers, and has resulted in the pressure of gases becoming more pronounced, and, as a consequence, nuisance is frequently experienced from sewer ventilators fixed at the road level or in other unsuitable places.

The remedy for this is not the abolition of traps, but the provision of adequate ventilation by means of fresh-air inlets and upcast shafts to the sewers. This duty of ventilating the sewers is one that devolves upon the public authorities under the Public Health Acts, and it is unfair that the sanitary authority should attempt to impose this duty on the owners of dwelling houses.

In cases where the requisite fall from the drain is difficult of attainment, there may be some slight justification for the objection which is occasionally urged against intercepting traps—namely, that they impede

the flow of the sewage; but in the majority of instances, if such difficulty does arise, it can be satisfactorily overcome by a careful consideration of the conditions. Another alleged drawback is that the trap is continually becoming choked, and, when fixed in a manhole, converts it into a miniature cesspool. But whatever may be said against intercepting traps, there is a general consensus of opinion that the trap, as a factor in the maintenance of freedom from offensive odours from drains and sewers, has come to stay—at any rate until a better substitute is found.

Intercepting traps may justly be described as the first line of defence against the issue of offensive emanations from the sewers, and disconnecting traps affixed to the various inlets the second line of defence. In addition, the latter prevent the emission of fouled air from the drains.

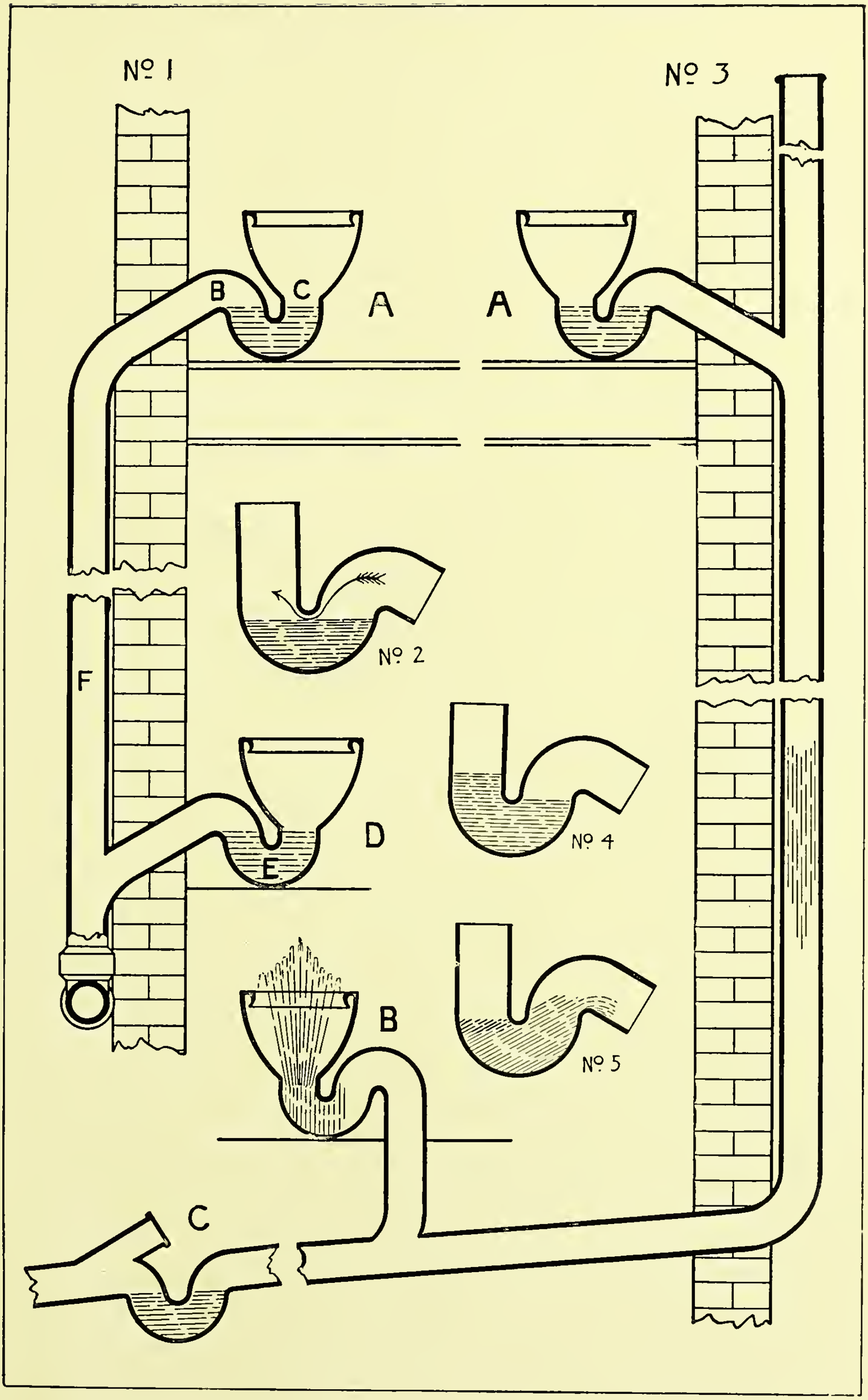
Traps Not All-Sufficient.—It must not be thought that the provision of a trap on the inlet side of the drain or waste pipe is all-sufficient, and that it will always perform its allotted task. There are constantly at work certain natural forces, which directly affect the efficacy of the trap as an agent for keeping back foul air. The waterseal is acted upon by—1. Siphonage; 2. Momentum; 3. Waving out or oscillation; 4. The expansion and compression of gases; and 5. Evaporation.

The action of **siphonage** can be most easily illustrated by No. 1, Plate XXIX, where F represents an unventilated soil pipe, to which two water-closet pans, A and D, are attached, both fitted with traps as shown. While quiescent, the water in the traps is in a state of equilibrium, the atmospheric pressure of 14·7 lb. per square inch being the same on both the exposed surfaces, B and C. Assuming that a pail of water is thrown down the upper water closet A, the water in passing into the vertical soil pipe would, to a greater or less extent, form a solid plug, which, in falling down the pipe, would drag with it a quantity of the air located in the upper portion of the pipe, the result being that a partial vacuum would be caused at B. The equilibrium of the forces acting on the surfaces of the water in the trap would be at once disturbed, the atmospheric pressure having been removed from the water at B, and, as a consequence, the pressure exerted at C would overcome the resistance of the water, and force some through the trap, until a vent was made for the air to pass under the dip and recharge the vacuum at B.

Directly a sufficiency of air had passed into the soil pipe, the siphonic action would cease, but during its action sufficient water would have been forced through to leave the trap *unsealed by siphonage*, as shown in No. 2, Plate XXIX.

Similarly, the seal of the bottom trap E would, in all probability, be broken by the siphonic action set up by the falling plug of water; or the operation could be reversed, the experiment being tried upon the lower water closet, when it would be found that the traps were acted upon until one or the other or both waterseals were broken. The same action will be found to occur in any case where a number of traps are connected to an unventilated waste or soil pipe.

Under the conditions set out, the lower trap E would most likely be unsealed from another cause. The plug of water, in falling down the



THE UNSEALING OF TRAPS

soil pipe, would quickly drive the air before it, with the result that the air in the branch pipe, not being able to escape elsewhere, would be compressed to such an extent that the pressure would blow the water out of the trap. This is a common occurrence where the branch soil pipe is unventilated and the drain is provided with an interceptor trap, notwithstanding that the soil pipe may itself be ventilated.

This can best be illustrated by No. 3, Plate XXIX, where A and B represent, respectively, two water closets, and C an intercepting trap in the drain. On discharging the upper water closet A, the contents of the trap at B would be forced out as shown. A quantity of the water would probably fall back into the trap and partly recharge it, but in many instances sufficient water is blown out to unseal the trap.

Momentum is the force set in motion by the quick discharge of a fairly large body of water into the trap attached to a sanitary fitting. The impetus given to the flow is such that a sufficiency of water to unseal the trap is carried away into the soil pipe. This is particularly the case where the waterseal or dip of the trap is small and the soil or waste pipe unventilated.

Occasionally it is a difficult matter to distinguish between siphonage and momentum, as the two forces often act in concert. There is, however, this difference, that siphonage rarely occurs where ventilation is provided to the trap and soil pipe, whereas momentum is possible even where proper ventilating pipes are present. Resistance against momentum depends in no small degree upon the strength of the waterseal, as represented by the length of the dip and the shape of the trap.

Waving out or **oscillation** is the disturbance of the water contained in the trap, caused by the alternation of the pressure exerted on the surface of the water on the outgo side, whereby the water is set in motion, and "waves" out over the weir of the trap into the soil pipe, leaving the waterseal weakened or broken.

This may be caused as follows. Air is compressible, and a plug of water, in falling down the soil pipe, as represented in No. 3, Plate XXIX, may compress the air contained in the pipe, and cause a pressure on the surface of the water in the lower trap at B, insufficient to force the water out of the trap as previously referred to, and yet quite sufficient to force the water up the inlet side of the trap as illustrated in No. 4. On the pressure being withdrawn, the water will rebound, and in so doing a quantity falls over the weir into the soil pipe as seen in No. 5. In cases where the trap has a small dip, the breaking of the seal will almost inevitably result; and in other cases, until the equilibrium is fully restored, the water will oscillate and wave out, and, by so doing, seriously weaken the strength of the seal.

Expansion and Compression of Gases.—Another factor specially relating to intercepting traps and sewers is the risk of the seal being forced by the compression of air in badly ventilated sewers, brought about by the sudden charging of the sewer with storm water, or to a smaller degree by the discharge of large quantities of hot water into the sewer. The rarefaction of the gases in unventilated sewers, which follows the raising of the

temperature, increases the pressure on the water contained in the interceptor traps, and presses back the water as illustrated in No. 4, Plate XXIX, until a passage is made for its escape under the dips of the traps into the house drains.

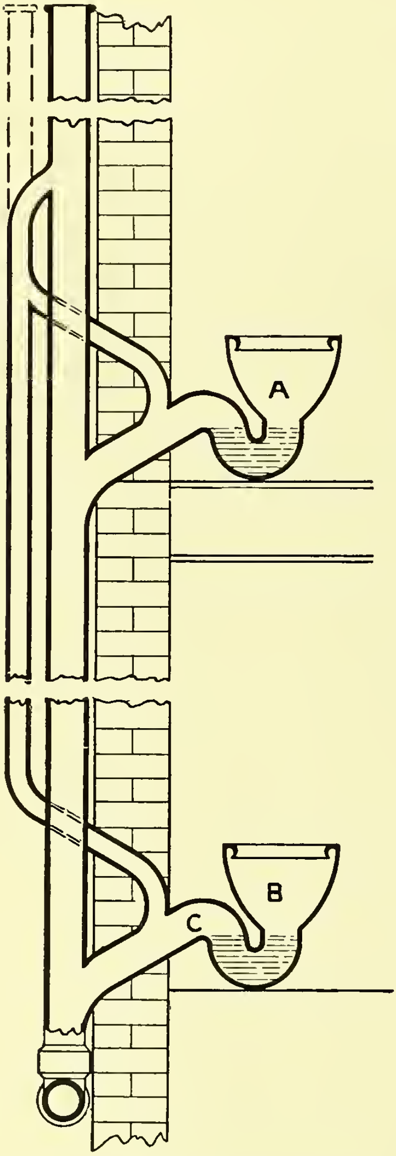


Fig. 445.—Ventilated Soil Pipe and Traps

Traps may also be unsealed through **evaporation**, and the greatest possible care should therefore be taken to ensure that the trap is kept charged by hand, if it is fixed in a position where it is rarely flushed by the discharge of waste water.

Broadly speaking, the ill effects of these natural forces can to a large extent be obviated by **adequate ventilation.** It has been shown that siphonage is caused by the existence of a vacuum or partial vacuum in the pipes to which the appliances are attached, the vacuum being due to the exhaustion of the air in the pipe by a falling body of water. If a vacuum can be avoided, siphonage of the contents of the traps cannot occur. Some traps are more easily siphoned than others, but of this more will be said later.

Ventilation of Soil Pipe.—From the top of the soil pipe in fig. 445, a vent pipe of the same diameter has been carried up for several feet. The effect of the open end is that the plug of water, in falling down the vertical pipe, instead of creating a partial vacuum, as in the case of the unventilated pipe shown in No. 1, Plate XXIX, draws into the open top of the vent pipe a supply of air to maintain the equilibrium, thereby preventing the siphonage of the trap of the upper water closet. The seal of the trap A is thus protected by the provision of a vent pipe, provided the branch pipe is not too long.

The same protection is not, however, given to the contents of the trap of the lower water closet B, fig. 445. The water, in falling from the level of the upper water closet to that of the lower, rapidly drives the air before it, which carries with it a quantity of the air contained in the branch soil pipe C, and before the incoming air following the plug of water can reach this branch the contents of the trap B may have been siphoned out.

This action does not, as a rule, occur where there is only one trap connected to the soil pipe, unless the soil and ventilating pipe is of great length, in which case the friction to be overcome by the air passing from the top of the pipe to the level of the trap is sufficient to retard the flow of air and permit the pressure to be relaxed on the water at the outlet of the trap, the result being that the contents of the latter would be pushed out by the atmospheric pressure exerted on the surface of the water on the inlet side of the trap. Where more traps than one are attached to the soil pipe, as in the case of Plate XXIX, siphonic action would be almost inevitable.

Trap-ventilating Pipes.—It is evident that in many cases the provision of a vent to the soil pipe is insufficient in itself to stop siphonic action, and experience has proved that the only safe method is the provision of trap-ventilating pipes, or "anti-siphonage pipes" as they are usually called, fixed in the position illustrated in fig. 445. The object of these pipes is fourfold. In the first place they provide a supply of air to the branch pipe and thereby prevent its conversion into the long leg of a siphon, and at the same time they prevent the air compression which produces waving out. Thirdly, they tend to mitigate the effects of momentum; and lastly, they prevent the accumulation of gases in the branch soil pipe with the resultant corrosion.

As momentum is closely allied with siphonage, the provision of sufficient ventilation will undoubtedly retard and mitigate its action. Momentum is not, unfortunately, always prevented by suitable ventilation. The suitability of the trap as to shape and strength of seal has much to answer for in this connection.

The size of anti-siphonage pipes must be regulated by the number of fittings discharging into the main soil or waste pipe. For soil pipes 4 in. in diameter the minimum size of the anti-siphonage pipe should be 2 in. For baths and lavatories it is usual to provide vent and anti-siphonage pipes of the same diameter as the waste pipes.

CHAPTER II

PIPES AND TRAPS

Materials.—Some kinds of pipe which were largely used prior to the inception of by-laws are now utterly banned. In this category would appear zinc, light sheet iron, painted or galvanized, and light cast iron of the strength known as "rainwater", all of which have been commonly used as soil pipes and ventilating shafts. Brick or barrel drains formed either of brick or stone, and unglazed earthenware pipes come also under condemnation.

Zinc is unsatisfactory for soil pipes, owing to the ease with which it is damaged and the rapidity of its corrosion, and the same remarks apply to pipes made of sheet iron coated with zinc. The coating soon disappears,

and corrosion quickly ensues through the action of the atmosphere, which rusts the iron pipe. Cast-iron pipe of rainwater strength is also unsuitable, for, although stronger than those previously mentioned, it is too thin to permit of the only suitable joint being made—that is, one made with molten lead properly caulked.

Unglazed earthenware is unsuitable for several reasons, among which may be mentioned its softness and porosity; and stoneware cannot be recommended for soil pipes, owing to the number of joints required, the difficulty of keeping them soundly fixed in exposed positions, and their liability to fracture.

Drains of the barrel type are objectionable because of their shape—which is generally rectangular—the difficulty of rendering them watertight, and the large fouling area which they possess.

The best materials for sanitary purposes may be classified under three heads: (1) Lead, (2) iron, and (3) stoneware.

Lead is the usual material for soil and waste pipes. Stoneware pipes are at the present day almost exclusively used, as far as domestic buildings are concerned, for underground drains; and iron pipes of heavy weight are now largely employed for soil, waste, and drainage purposes, and are daily coming into greater vogue, especially for soil pipes and underground drains.

Lead Pipes.—The advantages of lead for soil and waste pipes can be thus summarized:—

1. A smooth internal surface, which is a merit of no mean importance.
2. Malleability, which permits of its adaptation to any position, and its neat appearance when properly fixed.
3. Durability.
4. The ease with which sound water- and gas-tight connections can be made with absolute security, due to the complete union brought about by the fusion of the metals employed.

It is unquestionable that the qualities of the metal render lead eminently suitable for soil pipes and waste pipes. On the other hand, owing to the ease with which it is damaged, it is not well adapted for positions where it would have to withstand rough knocks and hard wear, and it is also more costly than certain other materials. Again, it is easily affected by changes of temperature, and the resulting expansion and contraction may unfit it for use, particularly where hot water in any quantity is conveyed.

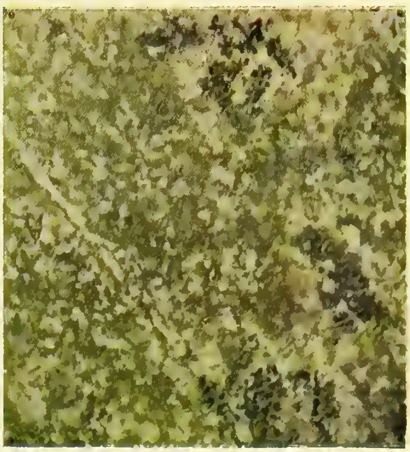
Lead is not the most suitable material for any and every position; but there is no doubt that its qualifications for some classes of work far outweigh its disabilities. As will be pointed out later, certain of the objections raised can be removed by a proper adjustment of the pipes and fittings to the varying conditions.

Cast-iron pipes of the thickness and weight now generally stipulated by by-laws possess great strength, and are capable of withstanding rough usage and heavy pressure both internally and externally. For these reasons they can be effectively fixed in situations where lead would be inappropriate. Iron pipes are cheaper than lead; the cost of fixing is less; and, if coated with a suitable solution and well maintained, they are fairly lasting. They

No. 9. VERDE ANTICO (GREECE)

No. 10. EGYPTIAN GREEN (EGYPT)

No. 11. SWEDISH



No. 12. LIGHT GREEN (SWEDEN)

GREEN MARBLES, ETC.

are not affected to the same extent as lead by sudden increases of temperature. On the other hand, the internal surface is rougher, and they are less adaptable and not so neat in appearance. It is also more difficult to ensure a perfect joint, as the usual method employed—*i.e.* that of caulking with metallic lead—consists of the mechanical compression of metals differing almost entirely in their characteristics. Joints of this description compare unfavourably with the fused joint used in connection with lead pipes.

Protection of Iron Pipes.—The smoothness and durability of cast-iron pipes may be improved by: (*a*) galvanizing, (*b*) steeping in a bituminous solution, (*c*) oxidizing, (*d*) glass- or vitreous-enamelling, and (*e*) metallic-enamelling.

In the galvanizing process the iron is first cleansed by steeping it in a solution containing sulphuric acid, and then scouring it with sand. After washing, it is dipped into a flux of chloride of zinc, and then immersed in a bath of molten zinc, which leaves a thin deposit on the surface of the iron.

The best-known bituminous solution is Dr. Angus Smith's, which is a mixture of pitch, coal tar, resin, and linseed oil, and is applied in the following manner:—The iron pipes, after being thoroughly cleansed, are heated to about 700° F., and are then steeped in the solution, which has been heated to 300° F., and are allowed to remain in it until an even temperature is obtained.

In the Bower-Barff oxidizing process the pipes are cleaned, placed in a chamber, and subjected to the action of superheated steam, which causes the formation of a film of black oxide upon the iron, rendering it impervious to the action of the atmosphere.

Metallic-enamelling consists in covering the iron with lead or oxide of iron paint.

None of these processes can be considered permanently satisfactory, as oxidation quickly takes place if the surface covering is scratched and the metal exposed. The least satisfactory methods are galvanizing and metallic-enamelling, both of which can only be considered as temporary expedients.

These methods of coating iron pipes prevent oxidation more or less perfectly, but do not convert the rough surface of the iron to a smooth state comparable with lead pipes. This is best secured by glass-enamelling —*i.e.* coating the iron when at a bright red heat with glass or vitreous enamel. By so doing a smooth surface is obtained impervious to the action of the atmosphere. Generally the insides only are enamelled, and the process can be carried out at about the same cost as galvanizing. The greatest care is needed in handling, cutting, and fixing glass-enamelled pipes, so as not to chip the enamel; for if this occurs, oxidation quickly ensues. For the outside a protection of some kind is needed, otherwise the value of the treatment is reduced by the corrosion of the external surface.

To secure the smoothness of lead and the strength of iron, **lead-lined iron pipes** have now for some time been manufactured. Drawn-lead pipes of a weight equal to 5 lb. sheet lead are tightly fitted to the inside of the iron pipes under pressure. The lead is turned outwards over the spigot

end of the pipe, and the joints are usually caulked in the ordinary way. They are, of course, more expensive than iron pipes, and this prevents their adoption except in first-class work.

Stoneware Pipes.—The third principal material employed is that known as vitrified stoneware, which is made by the admixture of clay, flint, and sand. The pipes are glazed, during firing, with common salt, which is placed in the kiln, decomposed by the heat, and as a vapour adheres to the ware. The salt fumes become incorporated with the material and produce a thin glaze of silicate of soda, which can only be removed by "chipping" the surface.

Earthenware is a different product, and consists merely of burnt clay. It is softer and more absorbent than stoneware, and cannot be recommended for general sanitary purposes. It is frequently employed, however, in the manufacture of agricultural pipes for subsoil drainage, for which purpose its use is permissible, as it is not essential that such pipes should be water-tight.

Stoneware pipes are largely used for underground drains, and also occasionally as waste pipes. If well glazed, the internal surface will resist the action of acids much better than iron; and, in fact, they should be exclusively used where there is a likelihood of such matter being discharged into the drain. On the other hand, the surface of stoneware is not very smooth, as any excrescences present before glazing continue to exist. The tensile strength of stoneware cannot be compared to iron, and its crushing strength is also much inferior. The joints are a source of weakness, on account of the large number required, and the uncertain condition of the cement used in the joints, and its liability to fracture under pressure.

From this short review the deduction can easily be made that, under ordinary conditions, the best material for soil and waste pipes is lead, and that for underground drains iron pipes are preferable to stoneware; but special conditions may demand a particular kind of material.

Pipes of various shapes have been used, but it is now generally agreed that the best shape is the cylindrical. The first essential of a sanitary pipe is that it should be self-cleansing, and the cylindrical pipe, properly laid, fulfils this requirement, whilst a rectangular pipe does not, and an oval or egg-shaped pipe is difficult to fix.

Evolution of the Trap.—It is not known which was the first form of trap to be brought into use—the round-pipe trap, or the too familiar D trap; but for many years the D type, in one form or another, held practical sway in the trapping of water closets, which were the only fittings, as a rule, to which traps were fixed. The form now generally accepted, and in many districts expressly required by the sanitary authority, is the round-pipe, siphon, or tubular trap, of which different forms are shown in Plate XXXI.

A good trap should possess the following qualities:—

(*a*) It should be self-cleansing, that is, capable of being flushed by an ordinary discharge of water.

(*b*) It should have a small internal surface, a smooth bore, a round section, and no square angles.

(*c*) The body should hold as small a quantity of water as is compatible with submerging the solid matter and the prevention of siphonage.

(*d*) The waterseal should approximate to 3 in. in depth, and be never less than $1\frac{1}{2}$ in.

(*e*) Its inlet should be larger than the throat, which should be reduced to a slightly smaller size than the outgo, so as to increase the velocity of the flow and thereby enhance its scouring force.

(*f*) The inlet should be shaped so that the matters discharged into it shall fall vertically into the water contained in the trap, and the smallest possible size should be used, having regard to the work to be performed.

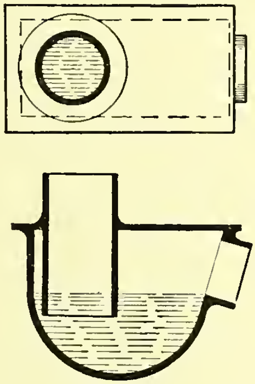


Fig. 446.—Plan and Section of D Trap

D Trap.—By a consideration of these points it will be easier to understand the defects of certain traps, such as the D trap, which is usually found fixed under an old water-closet apparatus. The most notable defects of this trap (fig. 446) are as follows:—

(1) It contains too large a body of water, and is never properly cleansed by an ordinary flush.

(2) Its internal surface is angular and too large, defects which allow it to become furred or encrusted.

(3) The lead dip pipe, which is unseen, is easily corroded by the action of the gases, the appliance becoming useless as a trap, and probably permitting the entry of bad air into the house.

It would be almost impossible for a D trap to be siphoned out or affected by momentum, &c.; but although this may be pleaded in its favour, a superficial examination of a trap of this type, which has been in use even for a short period, is quite sufficient to secure its condemnation. It is indeed a small cesspool.

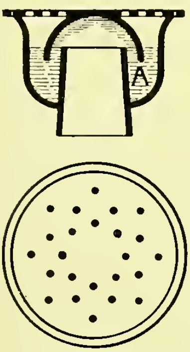


Fig. 447.—Section and Plan of Bell Trap

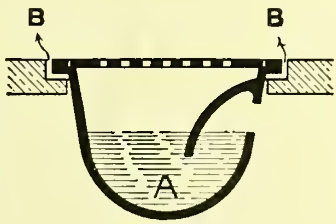


Fig. 448.—Lip Trap

Bell Trap.—A trap much in vogue for many years for sinks and surface drains is the well-known bell trap shown in fig. 447. These traps contain a very small quantity of water in comparison with the D variety, and the waterseal is usually about $\frac{1}{4}$ to $\frac{3}{8}$ in. in depth. The waterway is also much restricted, and the bell is removable. The bell top is generally perforated by a few small holes, which are always becoming choked; and for this reason the bell is usually lifted out of its proper place to provide a free outlet for the waste water. When the bell is removed, the fitting ceases to be a trap.

Lip Trap.—A slight improvement on this trap is the one shown in fig. 448, and known as a "lip" trap. Here, again, the waterseal is so

small as to be ineffective, and the trap is certainly not self-cleansing.

Both the bell and lip traps are commonly cemented into sinks and drip stones, as illustrated in fig. 448. The joints are usually found to be defective, permitting the escape of offensive odours at B; and neither of these traps will stand, as a rule, the ordinary smoke and chemical tests applied to drains.

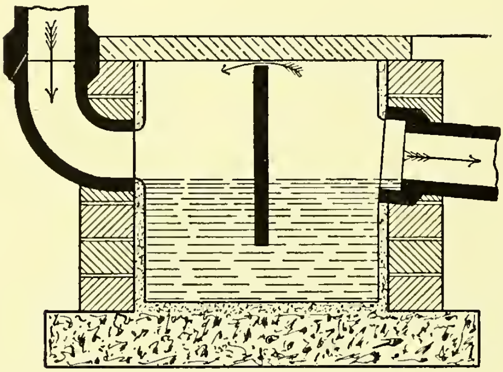


Fig. 449.—Mason's or Dip Trap

For the reception of waste water from sinks, the **Mason's or dip trap** (fig. 449) was at one time a great favourite; but traps of this type are simply receptacles for the accumulation of grease and other decomposing matter. They contain a large quantity of water, varying in capacity from 2 to 10 cu. ft., which no ordinary flush can possibly displace, and they cannot by any stretch of the imagination be deemed self-cleansing. Constructed of brickwork—not always rendered—they are fitted with a "dipstone" in the centre, as shown, for the purpose of providing a waterseal. More often than not, the dipstone is useless, owing to the negligence displayed in its construction, the joint between the dipstone and the cover being imperfect, thereby allowing the inlet side of the trap, as well as the waste pipes discharging into it, to be in direct communication with the drain.

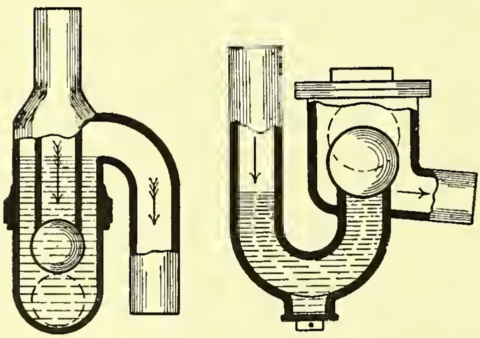


Fig. 450.—Mechanical Traps

All these traps are now prohibited by a large number of sanitary authorities, as expressed in their by-laws, of which the following extract is an example:—" A person . . . shall not construct or fix in or in connection with any such drain any trap of the kind known as a bell trap, a dip trap, or a D trap" (London's Drainage By-laws).

Mechanical Traps. — It has been thought by some engineers that a trap possessing only a waterseal does not afford sufficient protection against the passage of noxious gases from the drains and sewers, so they have made and patented what in their opinion are additional safeguards in the form of mechanical traps, two of which are illustrated in fig. 450. These traps are fitted with valves in the form of a ball, one in the body of the trap, and the other at its outlet close to the junction with the waste pipe, the idea being that the waste water will readily depress or lift

the ball and find an outlet, and that the ball will then assume its original position, keeping back the flow of fouled air from the drains. Other types of mechanical traps have a hinged valve instead of a ball.

Speaking generally, these valves are somewhat of a snare, except in their application as tidal valves, to which attention will be directed later on. They obstruct the full way of the trap and impede the flow, and the lodgment of a piece of paper or other particle of waste matter at once suffices to upset the proper working of the valves, which soon get out of order and become fixed in one position, and are thus rendered useless.

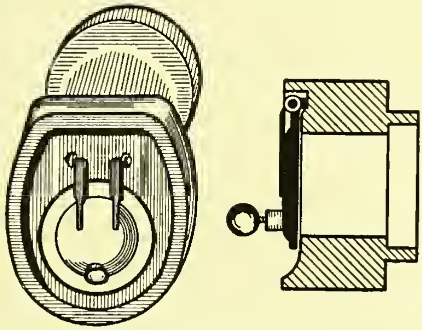


Fig. 451.—Flap Valves

A full clear way is indispensable in a good trap, and any impediment is to be deprecated.

Flap Valves.—Attention may be directed to the hinged flap valves used at the discharging end of drains, as shown in fig. 451. Occasionally it is asserted that these valves serve the purpose of keeping out sewer gas from the house drain, and at the same time prevent the back flow of sewage in time of storm. On consideration it is apparent they perform neither of these services. For a little while they may possibly do their work fairly well; but the hinges quickly rust or stiffen, and they then become fixtures. They are also liable to be held up by floating solid matters when discharging. In either case they fail to perform their allotted task.

Gully Traps.—In fig. 452 are illustrated two forms of trap intended for use as a

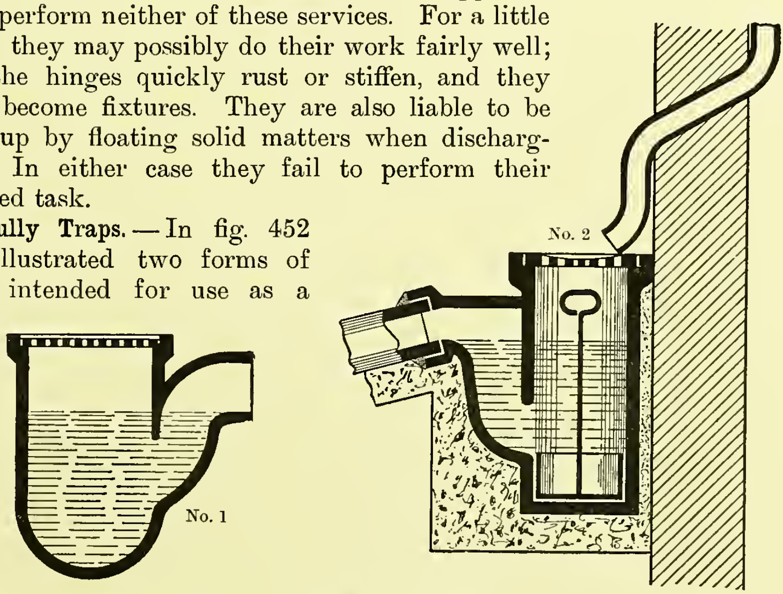


Fig. 452.—Yard Gullies

yard gully and for the reception of sink and other waste pipes. They have a large internal surface and contain a considerable body of water, and consequently are quite unlikely to be cleansed by the waste water from a sink or bath discharged, for instance, through a 2-in. pipe. Such a fitting may be suitable enough for the drainage of yards and open

spaces where there is a likelihood of a large quantity of detritus being washed into it, although even for this purpose better examples are available; but when used for greasy or soapy water from sinks and baths, it becomes a depository for foul-smelling semi-solid matter, and often occasions an insupportable nuisance. An additional drawback to No. 1 is the rounded base, which makes it difficult to fix in a level position. No. 2 is frequently used as a grease trap and for the reception of waste water. It is provided with a metal tray to receive any deposit that may accrue, the tray being fitted with a handle so that it can be lifted out bodily. This type is also unfitted to receive waste water, but can be satisfactorily employed for surface drainage.

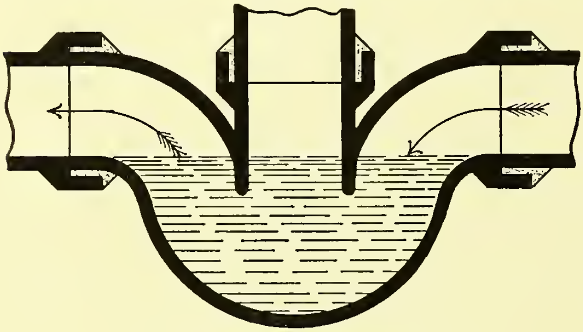


Fig. 453.—Defective Intercepting Trap

Intercepting Traps.—One of the worst forms of intercepting trap is shown in fig. 453. Amongst its defects are the following:—(1) Too large a body of water (a 6-in. trap of this type holds 18 to 24 pints as compared with the 9 pints which an ordinary interceptor of the form shown in No. 7, Plate XXXI holds); (2) inlet and outlet at the same level, which causes the solid matters to float on the surface of the water instead of being pushed through the trap by the velocity induced by the falling of the discharge over the weir as illustrated at A, No. 7, Plate XXXI; (3) badly situated central outlet, intended for an inspection pipe, but which generally becomes choked; (4) it is unprovided with a base, and for this reason is often fixed so much out of level as to abolish altogether its waterseal.

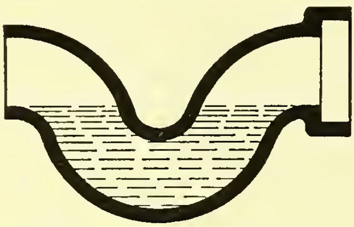


Fig. 454.—Defective Intercepting Trap

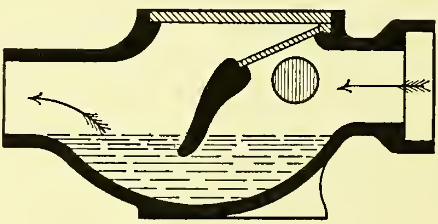


Fig. 455.—Defective Intercepting Trap

A modification of this trap, without the central opening but with certain of the other faults, is shown in fig. 454; and fig. 455 illustrates a modern type of interceptor that is not entirely free from objection, although provided with means of access both to the trap and to the drain inlet. The shape is such that solid matters would be liable to remain in the trap, until forced through by a second discharge.

Round-pipe Traps.—The more efficient traps of modern type now call

for notice. Of those designed for attachment to sanitary fittings the round-pipe or siphon trap is the best self-cleanser and is suitable for water closets, baths, sinks, and other appliances. These traps (Plate XXXI, Nos. 1 to 4) are made with the outgo in different positions, and are known as "S", "Half-S", and "P"; when the inlet and outlet are horizontal, the trap is known as a "running" trap. They can be had in either cast or drawn lead, which should be at least equal in thickness to sheet lead weighing 8 lb. per superficial foot.

The only objection to the use of a well-made and properly fixed trap of this kind is its liability to momentum and siphonic action. An improved form of trap, called the Anti-D trap (fig. 456), was invented and placed upon the market some years ago by an eminent plumber, who claims that, if properly ventilated, it cannot be unsealed by either momentum or siphon-

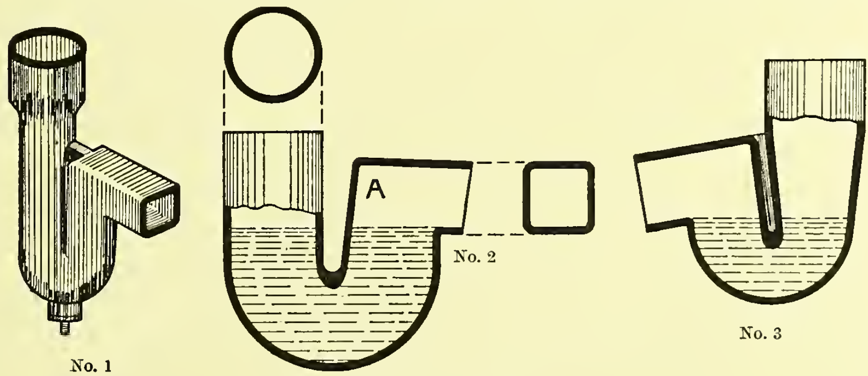


Fig. 456.—Anti-D Traps

age. The illustrations show that it is a variation of the siphon trap, its principal characteristics being: (*a*) an enlarged inlet, (*b*) a reduced waist, (*c*) an outgo square in section, (*d*) a waterseal $1\frac{3}{4}$ in. deep. With an enlarged inlet and a reduced waist the scouring force of the water is increased, and the squaring of the outgo makes it difficult for a vacuum to form at A (No. 2). This form of trap contains a very small quantity of water, the one shown in No. 3, which is suitable for a water closet, holding $2\frac{1}{2}$ pints only.

The fact that most by-laws now in force require all traps used to be of the siphon type—that is to say, tubular in shape—limits the necessity of description to those already dealt with.

Cleansing Screws.—Traps intended for fixing under lavatory basins and sinks should be fitted with a cap and screw for cleansing purposes, as shown in Plate XXXI, Nos. 1 to 4, but care must be taken that the cap is situated below the water line. This will ensure the immediate detection of any defect. Bath traps, if their position is easily accessible, should also be fitted with cleansing screws, but it is never advisable to provide a cap and screw to a closet trap. This is sometimes done, but generally, if fixed below the water line, they are useless owing to being inaccessible, and if fixed at the top of the trap there is a risk of an escape of fouled

air from the soil pipe. As a matter of fact they are usually unnecessary, as the trap can be reached by the hand from the closet basin.

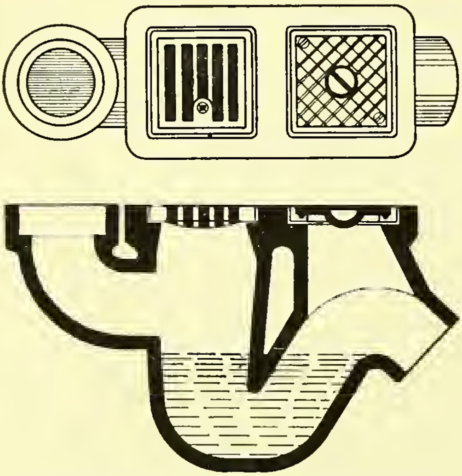


Fig. 457.—Disconnecting Trap with Back Inlet, Locked Grating, and Access Plate

Materials. — Apart from the traps forming an integral part of water-closet apparatus, the material usually employed in the manufacture of traps for indoor use is lead. To a smaller extent iron, brass, and copper (polished or nickel-plated) traps are also used. The best material is lead. Cast brass and iron traps have a rough internal surface, and require lining with glass or porcelain enamel.

Disconnecting Traps. — Plate XXXI, No. 5, illustrates a suitable disconnecting trap for ordinary waste pipes, where the amount of greasy water discharged is not sufficient to call for special treatment. Such a trap will satisfactorily receive the waste water from baths, lavatories, and small scullery sinks. It is provided with a back inlet for the sink waste, and can also be had with a side inlet as shown. Another good trap (No. 6, Plate XXXI) has a clearing arm, fitted with a stopper for obtaining access to the branch drain, but for this purpose the **P** form of trap is better than the **S** trap shown. **P** traps of this kind were used for all the gullies in the system of drainage shown in Plate XII, Vol. I.

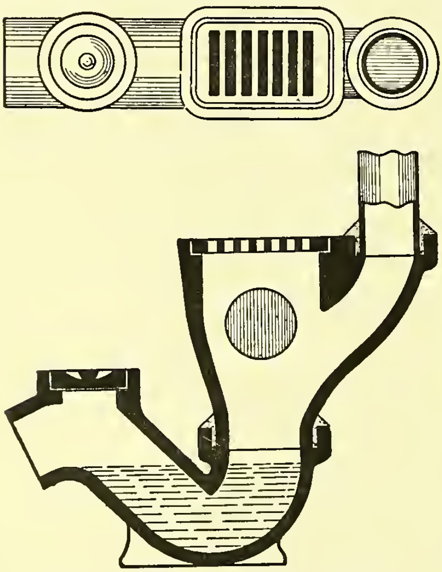
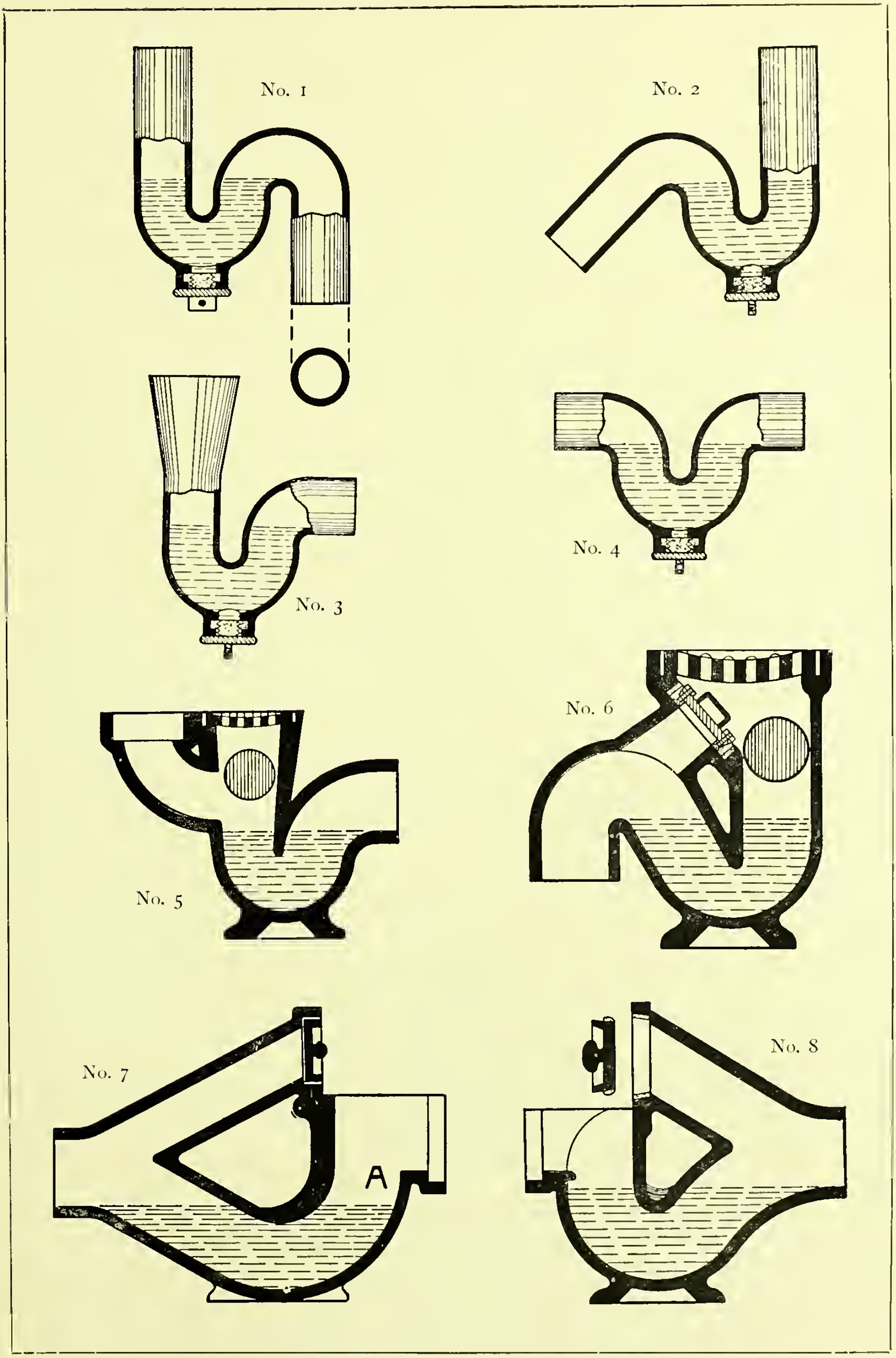


Fig. 458.—Disconnecting Trap and Connector

For schools and other places where special fittings are required, an excellent type of trap is that shown in plan and section in fig. 457. A back inlet is provided, a locked grating is fitted to the gully top, and a plate fastened with screws is fixed over the clearing arm.

A useful form of disconnecting trap, intended for the reception of waste pipes from groups of fittings, is shown in fig. 458. It is made in two parts—the trap itself, and a connector arranged to receive two or three waste pipes. The great advantage of this movable connector is that it can be turned in any direction to suit the waste pipes. It is also fitted with an access hole at the outgo of



TRAPS FOR WASTE PIPES AND DRAINS

No. 1, "S"; No. 2, "Half-S"; No. 3, "P"; No. 4, "Running" or "U"; No. 5, Disconnecting; No. 6, Disconnecting with Clearing Arm; Nos. 7, 8, Intercepting for Manholes.

the trap. A somewhat similar fitting can be used for connecting a number of branch drains to one gully, as in the case of the gully in the yard of the house shown in Plate XXXIV.

Where it is necessary to connect the waste pipes from a number of fittings to one disconnecting trap below the level of the grating, the reversible connector shown in section in fig. 459 will be found exceedingly useful. It is made with from one to four side inlets, and with an opening at the top, in which a grating can be placed.

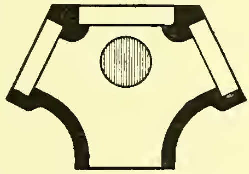


Fig. 459.—Reversible Connector

Gratings for Gullies.—The five-hole cover stone is still occasionally met with, in some cases having been refixed over gully traps, access to which it effectually blocks. The holes are too small and few, and are never clear for long together. Stoneware covers are easily broken, and the drainage holes are, as a rule, miserably inefficient.

Gratings for gullies should be strong and preferably made of iron, well galvanized, and with the openings as large as possible (consistent with keeping out extraneous matters), so as to admit a plentiful supply of air to the inside of the trap. For certain purposes it is specified that the bars must not be more than $\frac{3}{8}$ in. apart, a size which can also be accepted for all ordinary purposes. A grating of this type is shown in fig. 460.

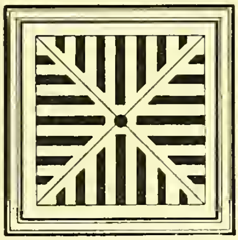


Fig. 460.—Cast-iron Grating

For the use of schools and other places where they are likely to be tampered with, locked gratings of the kind illustrated in fig. 457 should be provided.

Grease Traps.—The treatment of greasy water discharged from the scullery sinks is one of the most difficult problems that sanitary engineers have to contend with. In large establishments it is frequently necessary to provide special appliances, for if the grease is allowed to flow into an ordinary gully trap, or directly into the drain, it coagulates on the internal surfaces of the traps and pipes, seriously impeding the waterway and eventually choking it. Another evil attaching to this direct discharge into the drain, in cases where the waste water is treated by a system of irrigation, is the liability of the soil becoming clogged with grease, and thereby rendered useless as a purifying medium.

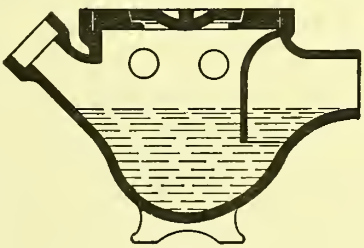
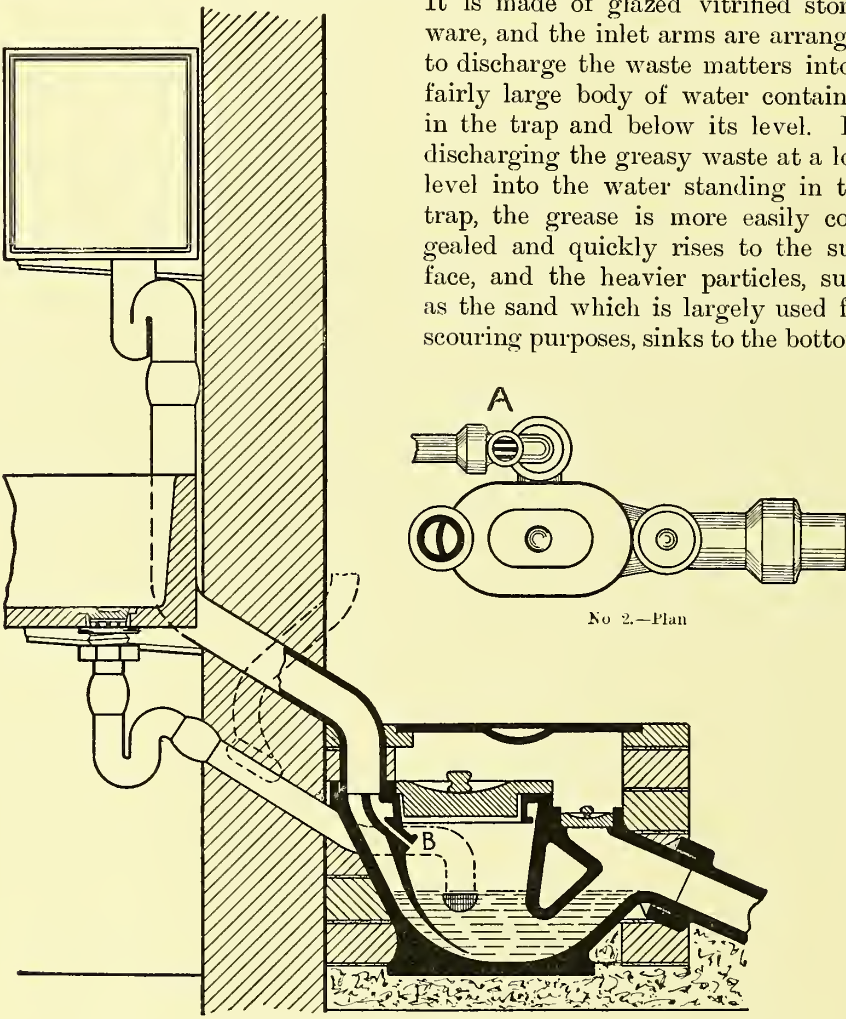


Fig. 461.—Flush-out Grease Trap

The question of the disposal of the grease can be considered from two distinct standpoints. Where a sewerage system is in existence, it is best to get rid of the grease as quickly as possible through the drain into the sewer; but if it is intended to convey the waste water to a cesspool, or to treat it by irrigation, the grease must be collected as soon after it leaves the sink as possible.

Fig. 461 illustrates one form of trap made in iron or stoneware, intended for use in conjunction with a flushing tank. It contains a fairly large body of water, and is fitted with a sealed cover.

An improved type of trap, designed to treat the greasy water from sinks where a sewerage system is in vogue, is shown *in situ* in fig. 462. It is made of glazed vitrified stoneware, and the inlet arms are arranged to discharge the waste matters into a fairly large body of water contained in the trap and below its level. By discharging the greasy waste at a low level into the water standing in the trap, the grease is more easily congealed and quickly rises to the surface, and the heavier particles, such as the sand which is largely used for scouring purposes, sinks to the bottom.



No 2.—Plan

No. 1.—Section

Fig. 462.—Grease Trap with Flushing Rim and Tank

The trap is provided with a flushing rim, and an automatic flushing tank is essential. The water discharged from the tank is split up into three portions, as will be seen by a reference to the section No. 1, one portion passing through the rim to cleanse the sides of the trap, another for breaking up the grease by way of the nozzle marked B, the third being utilized for washing out the solid matters deposited in the bottom of the

trap. These traps can be fixed above or below the ground level. A chamber as illustrated is not absolutely necessary if the trap is fixed below the ground, but is required if the trap is placed in an exposed position. A fresh-air inlet is provided to the waste-pipe connection as shown at A, No. 2, as well as a clearing eye and a suitable cover.

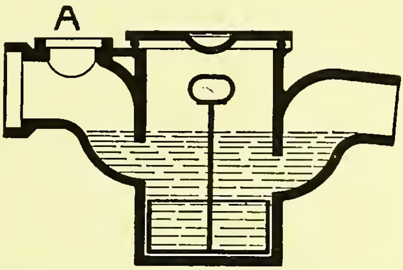


Fig. 463.—Trap with Lift-out Tray to retain Grease

Flushing tanks for these traps should be capable of discharging about 20 gal. of water at each period, which would vary according to the quantity of greasy water to be dealt with. They are usually made of wrought iron, galvanized, and should be fixed inside the premises, at least 5 ft. above the trap, so as to secure an adequate head of water. Tanks arranged for this purpose are fitted with a lead or iron flush pipe and siphon 3 in. in diameter, and are provided with a reverse-action ball valve.

Catch Grease Traps.—Where it is necessary to catch the grease, and prevent its escape into the drains, an entirely different form is required. Fig. 463 illustrates a form of trap that is largely used. It is made in iron or stoneware, and has a double seal. A lift-out metal tray to collect the grease is fitted, and the top is provided with an air-tight cover. The trap is provided with a back inlet, and fresh air can be admitted at A.

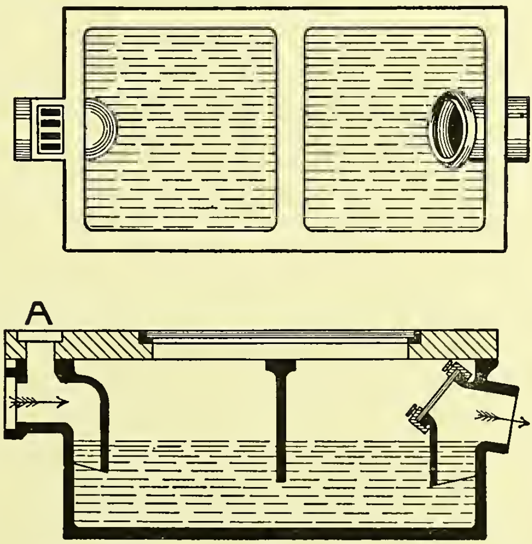


Fig. 464.—Trap with Two Chambers to retain Grease

In fig. 464 is shown a trap in plan and section, also made in iron and stoneware, which has been successfully employed. It consists of a double chamber with an inlet and outlet, a cleansing eye on the outgo, and a galvanized-iron cover bolted down. A fresh-air inlet is provided at A. The necessity for a large body of water is obvious. The waste water as discharged from the sink is usually warm, if not hot, and consequently the grease is split up into very fine particles and would float through an ordinary trap, containing only 6 to 10 pints of water, into the drain. To prevent the grease escaping it is necessary that it should be rapidly solidified, and this can only be effected by passing it into a large body of water at a lower temperature, or through a chamber inserted in a water jacket. The form of trap illustrated is made to hold from 6 to 26 gal. of water. Although at first sight a grease trap of this

description is comparable to the old Mason's or dip trap, it is really much superior to it. It is absolutely water-tight; there is no possibility of aërial communication between the inlet and the outlet; and, on the top being removed, it can easily be emptied and cleansed.

The position of grease traps deserves consideration—particularly those of the last-mentioned type — for the reason that, during the process of emptying, which in large houses is necessary about once a week, they are apt to prove a source of nuisance. Unless impracticable, the position chosen should be outside the walls of the building, for these traps are, of course, drain inlets, and as such would not be allowed in some places inside the premises. Where the circumstances are such that the fixing of the trap inside the scullery is obligatory, the greatest possible care should be taken to ensure the provision of a proper air-tight cover and its careful maintenance, and the outlet should be disconnected from the drain by being connected to a trapped gully outside.

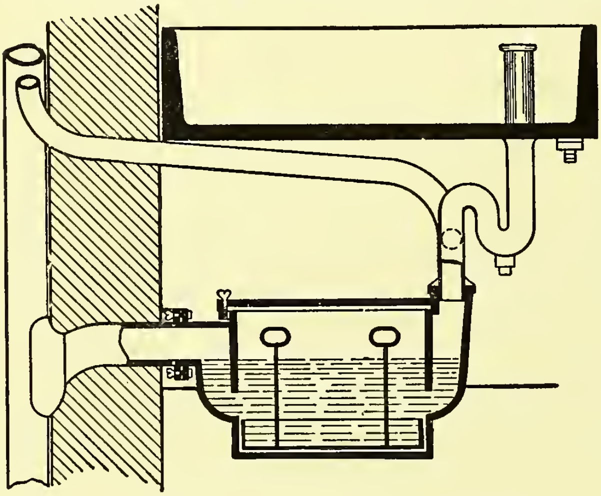


Fig. 465.—Grease Trap for Indoor Use

The trap illustrated in fig. 465, which is made of iron and provided with a suitable air-tight cover, has been specially designed for indoor use, the inlet and outlet being placed so as to make it easy to connect to the sink trap and waste pipe.

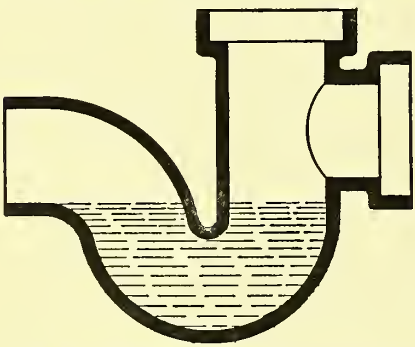


Fig. 466.—Intercepting Trap for Fixing in a Line of Drain Pipes

Good Intercepting Traps. — The special requisites of a good intercepting trap are an efficient cascade action and a cleansing arm. To provide the cascade, the invert of the inlet must be one or more inches above the level of the standing water, as indicated at A, No. 7, Plate XXXI, so that the inflowing waste matters from the horizontal drain shall fall on the surface of the water with sufficient velocity to be carried through the trap. A cleansing arm is necessary to obtain access to the sewer side of the trap in case of a stoppage. In Nos. 7 and 8, Plate XXXI, are illustrated two stoneware traps suitable for fixing in a manhole or inspection chamber. They are intended to receive U-shaped channel pipes, and for this purpose are provided with inlets of a similar shape.

Another kind is shown in fig. 466, which is designed to be fixed independently of a manhole; it is provided with an opening on the inlet side, suitable for inspection or for use as a fresh-air inlet or ventilating shaft. A flat base under the body of the trap, as shown in fig. 469, is an improvement.

Nos. 1, 2, and 3, fig. 467, illustrate in section the shapes now often adopted for the inlet, throat, and outlet respectively of interceptor traps, the alteration of the throat from a circular to an egg-shaped form having been proved to render the trap more self-cleansing.

No. 1 No. 2 No. 3

Fig. 467.—Cross Sections of Intercepting Trap No. 1, Inlet; No. 2, Throat; No. 3, Outlet.

Cleansing-arm Stoppers.—Sometimes the clearing arm is found to be stopped with a wooden plug, or a piece of slate bedded in cement, but such a method is improper and unsafe. Clearing arms should be fitted with stoppers that are capable of effectually sealing the orifice. Quite a number of different methods are in use. In the case of stoneware traps, the stopper may be of the same material and cemented in, in which case neat Portland cement should be used, or the stopper can be attached by a bituminous joint, either bevelled as shown in No. 8, Plate XXXI, or screwed, grease being used as the cementing material. Rubber expansion joints—on the same principle as the drain-stoppers used for testing purposes—and iron or gun-metal flanges bolted down, are now often used. In cast-iron traps the clearing arm should have a flange, to which a cover, with a packing of india-rubber or asbestos, can be bolted with galvanized-iron or gun-metal bolts and nuts.

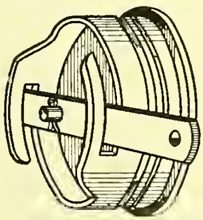
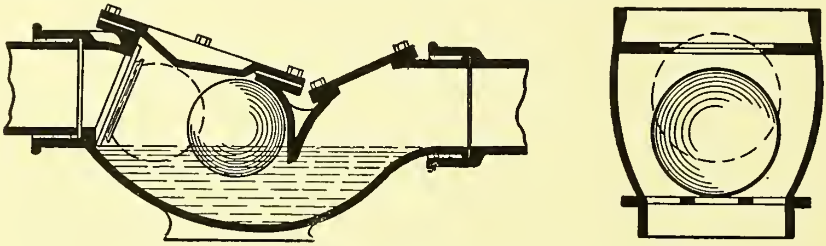


Fig. 468.—Clearing Arm with Metal Valve and Lever

A somewhat special feature of the clearing arm, illustrated in fig. 468, is that, instead of being fitted with an ordinary stopper, it is provided with a metal valve manipulated by a lever, to which is attached a chain pull carried to the ground level. In the event of the disconnecting trap becoming choked, and the manhole flooded with sewage, the valve can be opened by means of the chain, and the contents of the manhole discharged through the clearing arm. This arrangement is not devoid of criticism, as there is always a danger of the valve being left open, whereby the object of the intercepting trap is defeated and sewer gas is permitted to enter the drains.

Tidal Valves.—A more efficient fitting than the flap valves previously referred to, for preventing the back flow of sewage from overcharged sewers, is what are known as "tidal valves". Two kinds are shown in fig. 469. No. 1 illustrates a combined intercepting trap and tidal valve, and No. 2 a separate tidal valve for connecting to the top of an ordinary gully or disconnecting trap. In both illustrations the valve takes the form of a ball. In No. 1 the ball is of copper, and a rubber seating is provided to the inlet of the iron trap, while a vulcanite ball with a gun-metal seating is provided in No. 2. The "backing up" of sewage matter from the drain, in each instance, presses the ball against the seating and

thereby closes the orifice. In other types of valve the ball is attached to a metal spindle with a hinged joint, instead of being entirely free. The principle, however, is the same. Where a tidal valve is attached to the



No. 1 No. 2

Fig. 469.—Tidal Valves

No. 1, With intercepting trap, copper ball, and rubber seating; No. 2, With vulcanite ball and gun-metal seating

main drain independently of the intercepting trap, it should be fixed between the latter and the sewer and surrounded by a chamber for the purpose of access.

In fig. 470 is illustrated a totally different kind of tidal valve, designed for use in localities which are subject to floods. It consists of a metal flap, working against the inlet of the interceptor and operated by a chain carried to the top of the chamber. It is non-automatic, and requires lowering by hand when a flood is expected. For this reason it is of less value than the ball type previously described.

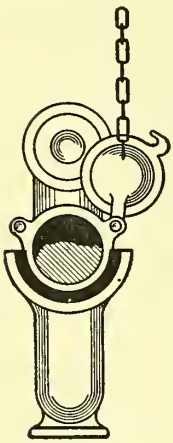
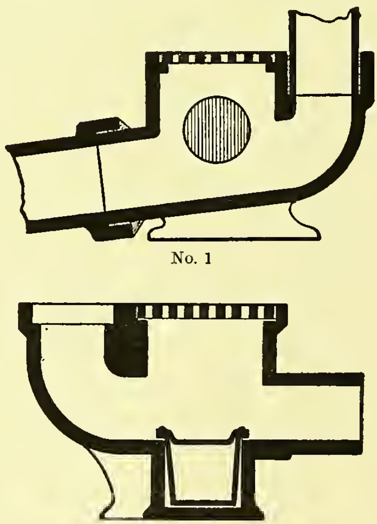


Fig. 470.—Non-automatic Tidal Valve



No. 1

No. 2

Fig. 471.—Rainwater Shoes

Rainwater Shoes.—Disconnectors for rainwater pipes are known as "rainwater" or "access" shoes. Two kinds are shown in fig. 471, one being provided with a silt bucket. The disconnector not only affords access to the drain and rainwater pipe, but also provides adequate ventilation, and, in the case of No. 2, fig. 471, a receptacle for the detritus from the roof.

CHAPTER III

SINKS

Number of Sinks Required.—The number of sinks required in any building must depend upon the size and description of the premises, the use to which they are put, and the number of occupants or separate families. In cottage property the provision of one sink in the scullery is usually considered adequate. For houses of a better class the need may vary from a general washing-up sink in the scullery or kitchen, with possibly a small drip sink on one of the upper floors, to the provision of a range of sinks and troughs in the scullery; butlers' pantry sinks; and a housemaid's sink (either alone or in combination with a slop sink) on each of the bedroom floors; in addition to a number of draw-off sinks. The planning of the house also has an important bearing upon the number required, especially as to housemaids' sinks on the upper floors. In hotels and some public institutions greater facilities are required for the washing up and cleansing of the various domestic utensils than is the case in ordinary households. For residential flats or suites of rooms, at least one sink is necessary in each suite. In tenement and artisans' dwellings of the block type, an endeavour should always be made to provide a sink for each tenement. In places of this description, where sinks are used in common by two or more tenants, it is an extremely difficult matter to secure that they are kept clean and in working order, and much friction is caused amongst the tenants in the event of one of their number being careless or dirty.

Where old-fashioned houses that were originally built for one family, have been converted into a number of separate tenements, it is, however, in many instances impracticable to provide a sink for each tenant, unless it is fixed in a room used either for living or sleeping purposes, which is a reprehensible practice. In such cases it is better to provide a sink on the half-landing for the use of the tenants who occupy the two adjoining floors.

Position.—Sinks ought never to be fixed in living or sleeping apartments. Dark and unventilated or badly ventilated positions should be avoided, and the apartment in which the sink is placed should have at least one external wall, and be provided with means for supplying direct external light and ventilation. If fixed in an insufficiently lighted situation there is always a tendency towards neglect, and, as a result, an accumulation of filth occurs with the attendant emission of offensive odours. The position chosen for the sink in the apartment should, without exception, be as close to the window as practicable, so as to obtain the maximum amount of light on the fitting. To keep the apartment in a sweet and inodorous condition, a constant change of air is also essential.

In many respects the isolation of sinks in a separate block, as illustrated for tenement houses in No. 2, fig. 541, is advantageous, as the fittings are thereby aërially disconnected from the residential portion of the premises.

For ordinary private houses, a modification of this system is possible by placing the sink in a small apartment projecting from the rear wall of the main building in the same manner as the water closet shown in No. 1, fig. 541. By this arrangement cross ventilation of the apartment can be easily secured.

Floor and Walls.—The use of wood in the construction of the floor and walls is objectionable, as it readily absorbs the foul water, which is frequently and often unavoidably splashed or spilled on the walls and floor, rendering the surroundings offensive and setting up decay of the material. Where the walls and floor are of wood they should be protected by a covering of sheet lead, tiles, or other impervious material. The wall against which the sink is fixed, if of common brick, ought never to be left in a crude state. A rendering of Portland cement, trowelled to a smooth face, should be applied, or, better still, white tiles of earthenware or glass. These materials present a good appearance, are non-absorbent, and are fairly inexpensive.

The floor is best constructed of concrete, covered with Portland cement or granolithic, glazed tiles, or asphalt. Unglazed earthenware tiles or bricks are not suitable for paving, owing to the number of joints, the ease with which they are loosened from their bed, and (in some cases) the porosity of the materials.

Materials for Sinks.—The materials used for sinks include wood unlined, wood lined with sheet lead or copper (tinned or untinned), zinc, tinned or galvanized sheet iron and steel, cast and wrought iron (galvanized or enamelled), white metal, vitrified stoneware, and enamelled fireclay.

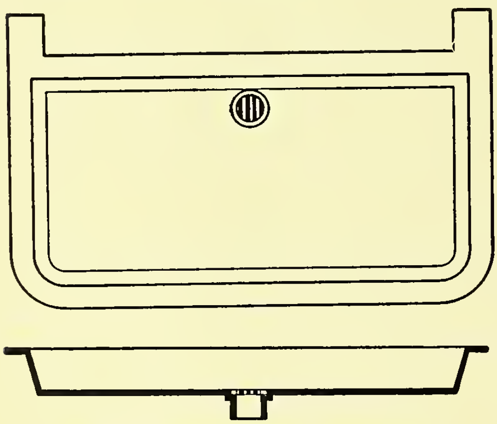


Fig. 472.—Plan and Section of Cast-iron Sink

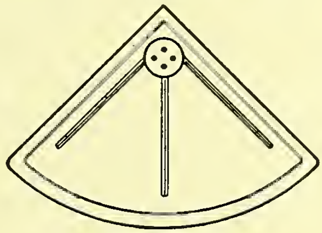
Whilst the use to which a sink is to be put governs the choice of materials, certain of these substances can be at once objected to as being unsuitable. Wood, except for a specific use to which reference will be made later, is objectionable, owing to the ready manner in which it absorbs filth. Zinc is too fragile and short-lived; sheet iron and steel, either tinned or galvanized, are not good materials, as the coating soon disappears, allowing corrosion of the iron to take place. The surface of sheet iron and steel sinks is rough, and the rivets and seams are apt to collect the dirt. Sinks made of plain cast iron present a dirty appearance and are difficult to keep clean.

The other materials, viz. lead, copper, white metal, stoneware, and fireclay are all suitable for use in special positions and for varying conditions. Stoneware and fireclay have now come into very general use, and for ordinary domestic purposes they are unquestionably the best, as they are

non-absorbent and easy to keep clean. Salt-glazed stoneware is stronger than enamelled fireclay, and the objection made to its dark appearance has been removed by the manufacture of a glazed ware of a buff colour.

Shallow **cast-iron sinks**, as illustrated in fig. 472, are often provided with a grated outlet, or one shaped in the form of a bell trap, and are either plain or vitreous-enamelled. The presence of sharp angles, which

No. 1



No. 2

Fig. 473.—Glazed Stoneware Sinks. No. 1, Oblong; No. 2, Angle

accumulate the dirt, is, however, an objection; and even vitreous-enamelled iron sinks are not altogether satisfactory, as the enamel is chipped off in the washing up of metal utensils. A slightly better form of iron sink is provided with a roll edge instead of a flat rim.

In houses of the cottage type **glazed stoneware sinks** (mostly oblong in shape), of the type shown in fig. 473, are usually fixed, the commonest size being 3 ft. by 1 ft. 8 in. by 6 in. The shallowness of this form is its

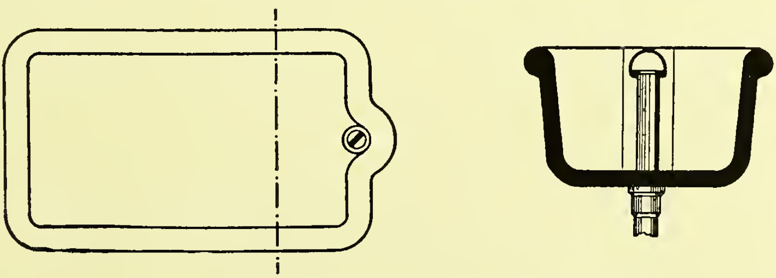


Fig. 474.—Deep Fireclay Sink with Roll Edge and Recessed Outlet

great drawback. A brass cobweb grating is better than the perforated stoneware grating shown in No. 2.

Fireclay Sinks.—An improved pattern is illustrated in fig. 474. The sink is made of white vitreous-enamelled fireclay; the internal depth is 9 in., the angles are hollowed, a roll edge is provided, and the waste outlet is recessed. By the use of a plug or standing waste the sink can be filled with water and used for washing-up purposes. Sinks of this type are now usually known as housemaids' or butlers' sinks.

A larger sink for good-class work, with a plug outlet, and fitted with lugs to receive a draining board inside the sink and a high skirting at the back, is shown in fig. 475. A more elaborate sink of the same material (fig. 476) has two compartments, one for washing up and the other for rinsing. The sink has a rolled edge, is fitted with separate plugged

outlets, and the back, which is 12 in. high, is formed in one piece of ware with the sink, and is holed to receive the taps. A solid back of this kind forms a notable improvement. The overflow is in the partition between the two compartments.

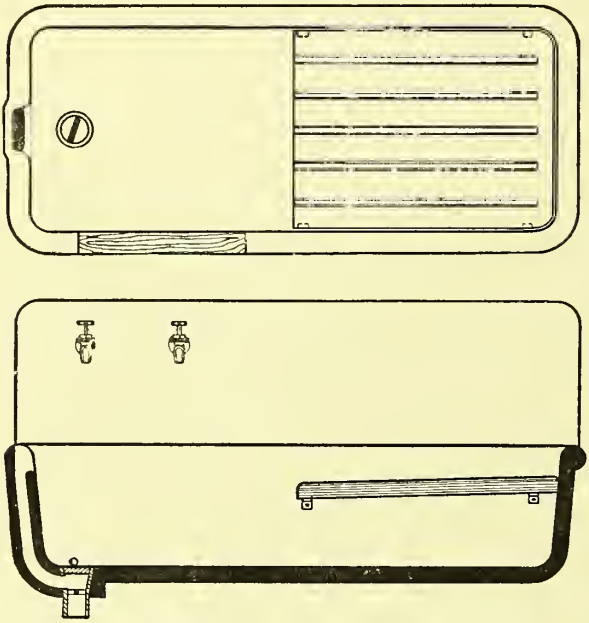


Fig. 475.—Sink with Plug Outlet, Lugs for Draining Board, and High Skirting

Metal-lined Pantry Sinks.—To the use of pottery, however, one forcible objection is heard, which is that the hardness of the material results in the breakage of much crockery. For this reason sinks made of a material that possesses greater resiliency are often advocated. First among these may be mentioned wooden shells fitted with a sheet-lead lining. Whilst lead is an excellent material for lining sinks reserved for a particular class of work, it is not the best for scullery sinks, as it is affected by the rapid changes of temperature due to the alternation of hot and cold water, which cause the lead to buckle and eventually to crack. It is also difficult to keep free from grease, and its appearance is not inviting. For a pantry sink there is slightly less objection to the use of lead, as fewer greasy utensils are cleansed. A better material than lead is tinned and planished sheet copper or white metal. Untinned copper is also used, but a great deal of labour is entailed in keeping it clean.

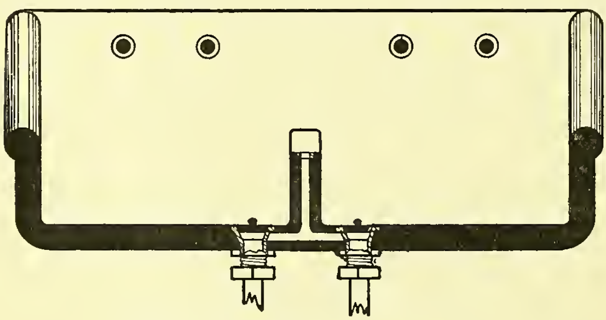


Fig. 476.—Sink with Two Compartments

In preparing **the wooden shell** for lining with lead or copper, the acute angles present in fig. 477 should be avoided, as they hold the metal rigidly in position, and tend towards the accumulation of dirt. The sides of the shell should be dovetailed together in preference to being bolted, and hollow fillets should be fixed in the angles, as shown in fig. 478,

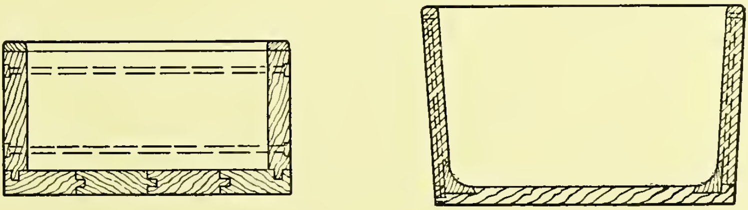
which will abolish the sharp corners and permit the metal to expand more freely, thus obviating the breakages that are sometimes due to the metal being too rigidly fixed. The sinks should not be severely rectangular in shape, the tapering sides illustrated in fig. 478 being far better than that shown in fig. 477, and the bottom should slope towards the outlet. It is necessary, where the metal is turned over the top edge of the shell, to protect it with a hardwood capping, as in fig. 477, to prevent its being pressed over and buckled.

Fig. 477.—Defective Wood Sink lined with Lead

Fig. 478.—Improved Wood Sink lined with Lead

Sheet lead[1] for forming the sides and bottom should be of the minimum weights of 6 and 7 lb. per superficial foot respectively; and **sheet copper** should weigh 4 lb. for the bottom and $2\frac{1}{2}$ to 3 lb. for the sides. Proper wiped or burnt seams should be employed for uniting the pieces of lead. The copper lining is generally made before being fitted into the shell, the sheets being welted together and then tinned. Copper-lined sinks while new can be kept in a clean state, but unless the copper is coated with a good thickness of tin the latter soon wears off, resulting in the sink bearing a patchy appearance.

Wooden Sinks.—The want of resiliency and the hardness and slipperiness of the surface of pottery sinks are most noticeable where the principal articles that are cleansed consist of plate, glass, and fragile china. For



No. 1 No. 2

Fig. 479.—Hardwood Sinks

this class of work unlined hardwood sinks of birch, teak, and mahogany are sometimes used, and, if properly made and carefully looked after, are suitable, provided they are not habitually used for the washing up of grease-encrusted utensils. The usual method of construction is to form a rectangular sink of the size required, and varying from 6 to 12 in. in depth, of wood $1\frac{1}{2}$ to 2 in. in thickness, having grooved and tongued joints, the sides and bottom being bolted together with painted or galvanized-iron bolts and the joints made water-tight by the use of red and white lead. A sink of this kind is shown in No. 1, fig. 479. Sometimes hollow fillets are fixed in the angles. A much improved shape is shown in No. 2, the 2-in. sides, ends, and bottom being mortised and tenoned together in a tapered form, with hollow fillets grooved into the solid.

[1] See also Section III, Chapter X.

Housemaids' Sinks.—In some large establishments housemaids' sinks are provided in combination with a slop sink, as illustrated later, but in other cases it is preferred to provide a separate fitting for use as a draw-off and wash-up sink. A good type of fitting for this purpose is that shown in fig. 475. In many houses it is impossible to fix a sink of this description owing to the want of a suitable position, and if a sink is to be provided for the convenience of the upper floors it frequently has to be arranged so as to fit into some odd corner of the landing or staircase. For such positions the fireclay angle sink shown in fig. 480 can be usefully employed. It is sufficiently large to admit of a pail being placed in it. Sinks of this kind are often adopted in tenement houses owing to the scarcity of available space, which prohibits a larger fitting. In this class of house the sink is best left exposed, even where situated on the staircase; but in houses of a better class a suitable enclosure should be provided.

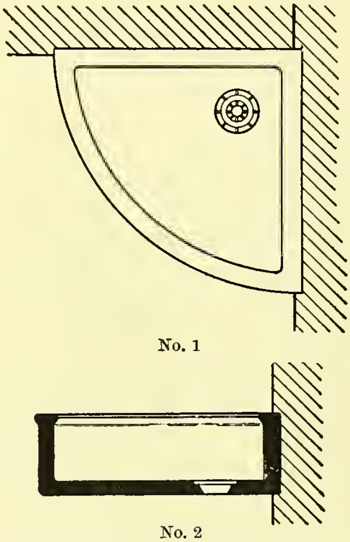


Fig. 480.—Housemaid's Fireclay Angle Sink

Occasionally a sink is required under a draw-off tap to catch the water that drips from the tap or is splashed during the filling of utensils. These sinks, known as **drip sinks**, are not intended for the reception of fouled water. It is a common practice to construct a sink for this purpose by enclosing a small portion of the floor with a wooden curb and lining the space with sheet lead, turned up against the skirting and over the curb, the latter being covered with a capping as shown in fig. 481. The glazed

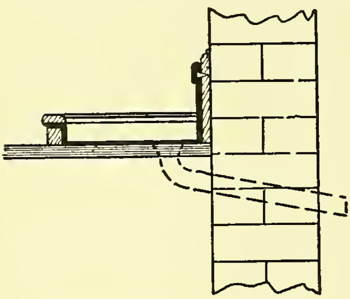


Fig. 481.—Lead-lined Drip Sink

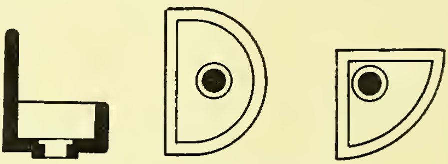
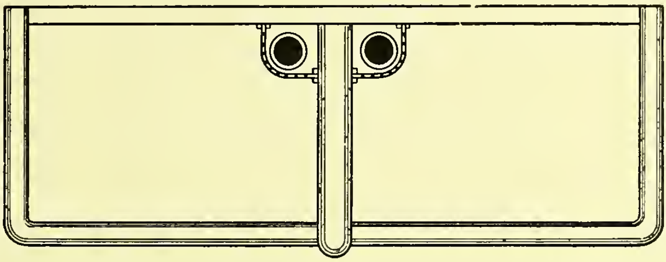


Fig. 482.—Fireclay Drip Sinks

fireclay flat back and angle sinks with high skirtings, illustrated in fig. 482, are, however, more suitable.

Vegetable Sinks.—In mansions and hotels sinks specially fitted for preparing vegetables are sometimes required. Deep fireclay wash tubs are admirable for the purpose, if fitted with an enclosed waste separated from the remainder of the sink by a perforated metal strainer to prevent dirt and grit finding access to the waste pipe. Sinks intended for this work are usually made of slate, galvanized sheet iron, or enamelled cast

iron, and sometimes of tinned copper. Fig. 483 represents a double sink with one compartment for washing and the other for rinsing. It is



made of enamelled fireclay, which is the material most worthy of selection. The sink is about 1 ft. 3 in. deep, has a high back, and is fitted with a standing waste, enclosed by a removable copper strainer, to prevent solid matters entering the waste pipe.

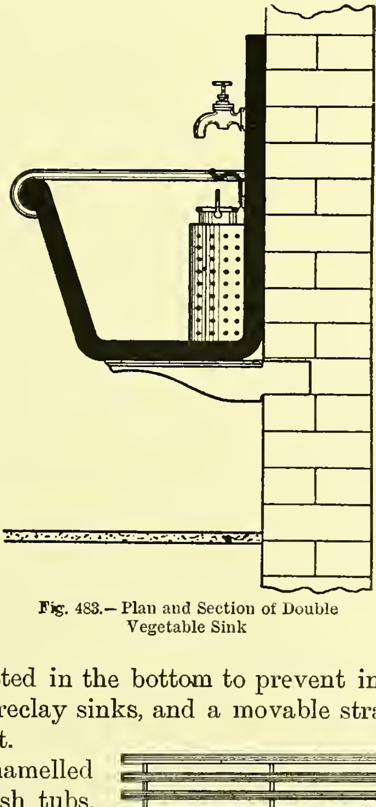


Fig. 483.—Plan and Section of Double Vegetable Sink

Scouring Sinks.—For general use iron sinks are not advocated, but for sinks intended for the scouring of copper and other metal cooking utensils the use of iron is permissible, although stoneware is to be preferred. Copper- and lead-lined sinks are liable to be damaged by metal utensils, and the surfaces of glazed sinks are apt to be scratched and roughened. In this kind of sink also the waste pipe ought to be enclosed by a perforated metal strainer to keep back the sand which is used for scouring purposes. If a special sink is not provided, a wooden rack, as shown in fig. 484, should be fitted in the bottom to prevent injury to the surface of enamelled iron and fireclay sinks, and a movable strainer should be placed over the waste outlet.

Wash Tubs.—Wood, galvanized and enamelled iron, and fireclay are employed for wash tubs, the last mentioned being the most suitable. Wooden tubs are more frequently employed than any other kind, owing to their cheapness and to the fact that they are not easily damaged. They are, however, much inferior to enamelled iron or fireclay, as they absorb the soap and filth, and, if neglected, become very offensive. Fireclay tubs are cleaner and more satisfactory, but the likelihood of damage deters the owners in many cases from fixing these in

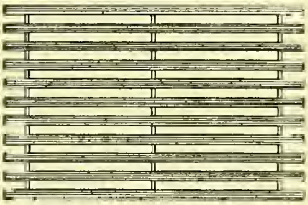


Fig. 484.—Wooden Rack for Bottom of Sink

certain classes of property. Vitreous-enamelled iron tubs are satisfactory, so long as the enamel is not chipped. Where this occurs, the clothes are likely to be stained. In figs. 485, 486, and 487 are illustrated respectively a slate trough with sloping front, fixed on iron standards; an enamelled iron tub with rolled edge and sloping sides, supported on painted cast-iron legs; and a fireclay tub carried on cantilevers.

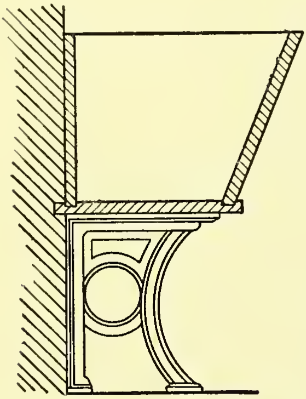


Fig. 485.—Slate Washing Trough

The inside measurements of wash tubs vary from 2-ft. by 1 ft. 8 in. by 1 ft. 3 in. to 3 ft. by 1 ft. 8 in. by 1 ft. 3 in.; but large cast-iron steeping tubs for laundry use, measuring up to 7 ft. by 3 ft. by 2 ft. 3 in., can be obtained.

Wash tubs are very useful in ordinary dwelling houses, but are particularly in demand in block and tenement dwellings, where, in addition to the sinks fixed for the use of individual tenants, one or more tubs in the common wash house are essential. The number of tubs necessarily depends upon the number of persons who have a right to use them habitually, and the usual manner of estimating the fittings required is to allot to each tenant the use of two tubs (one for washing and the other for rinsing) on one day or half-day in the week. Thus, on the half-day basis, and reckoning five working days per week, two tubs would be sufficient for ten tenants. When provided in private houses, at least two tubs should be fixed.

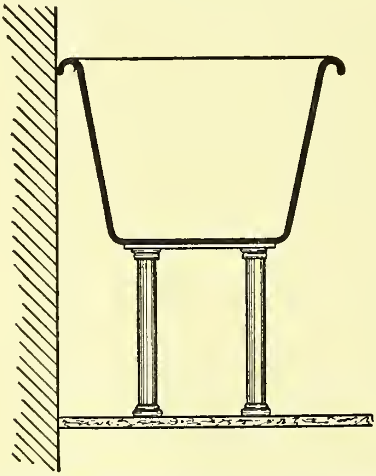


Fig. 486.—Enamelled-iron Wash Tub on Cast-iron Legs

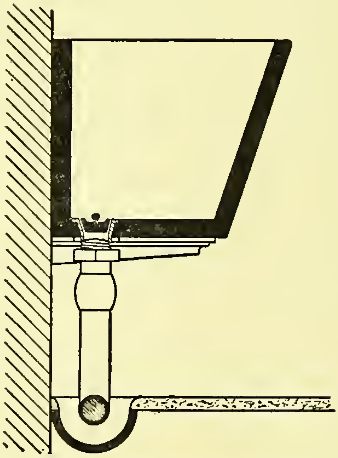


Fig. 487.—Fireclay Wash Tub on Cantilevers

For use in **chemical laboratories and works**, the primary qualification for a sink is its acid-resisting qualities. Zinc and iron (either plain or galvanized) are useless, as the metals are quickly destroyed; for so powerful is the action of the various acids that even vitreous or porcelain enamel is in many cases quite incapable of resisting the dissolving process which

takes place. Lately, an exceedingly hard vitreous enamel has been manufactured for the purpose, but, speaking generally, the only material that is perfectly satisfactory is salt-glazed stoneware.

Soldered and Burnt Seams.—In the making of lead-lined sinks, and in covering draining boards or counters, for laboratory use, the pieces of lead should never be united by soldered seams, as the tin contained in the solder is liable to corrosion. With shallow sinks the corners can be bossed up. If the depth of the sink does not permit of this, the pieces of lead must be burned together. For drainers and counters, the seams should be either lapped or burnt. The methods of construction are otherwise the same as previously described for ordinary sinks, but the minimum weight of lead

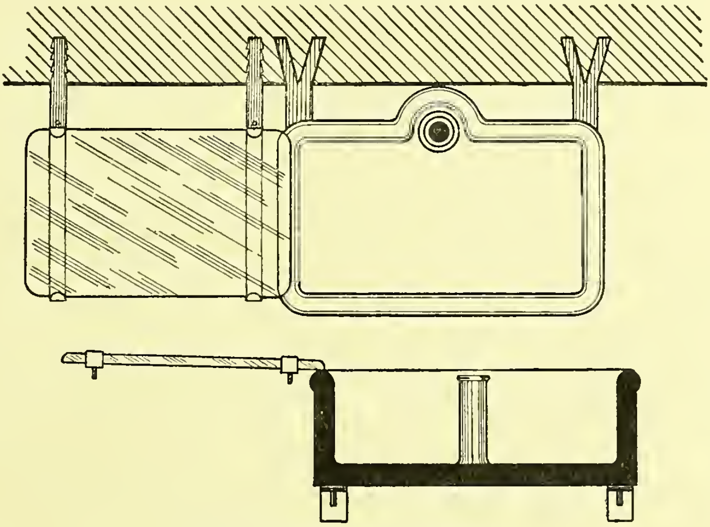


Fig. 488.—Hospital Sink on Cantilevers

used should be 7 lb. for the sides and 8 lb. for the bottom. For good work 10 lb. for the sides and 12 lb. for the bottom ought to be employed.

Reference will be made to **combined wash-up and slop sinks** in the chapter dealing with the latter.

Hospital Sinks. — Washing-up sinks, distinct from any form of slop sink, are, however, often required in hospitals, infirmaries, and mortuaries. The material employed must necessarily be non-absorbent, and capable of quick and easy cleansing, and all sharp angles and corners, in which dirt would be likely to accumulate, must be dispensed with. There is no material which is so suitable as porcelain-enamelled fireclay. An excellent type of sink for hospitals is the one illustrated in fig. 488. The material is fireclay, the standing waste is recessed, and the sink is made with a roll edge all round, so as to be fixed clear of the wall on cantilevers as shown. Special sinks are made for operating theatres, fitted with waste and supply valves operated by foot, knee, or elbow pressure.

Post-mortem Slabs.—For conducting post-mortem examinations in mortuaries, proper tables or slabs of the kind illustrated in fig. 489 to 491 are now

considered indispensable. In size they vary from 6 ft. by 2 ft. to 6 ft. 8 in. by 2 ft. 7 in., and the materials employed include rubbed and oiled slate, polished marble, cast iron porcelain-enamelled, and white glazed or enamelled fireclay. Fireclay is the most suitable material, but for movable tables

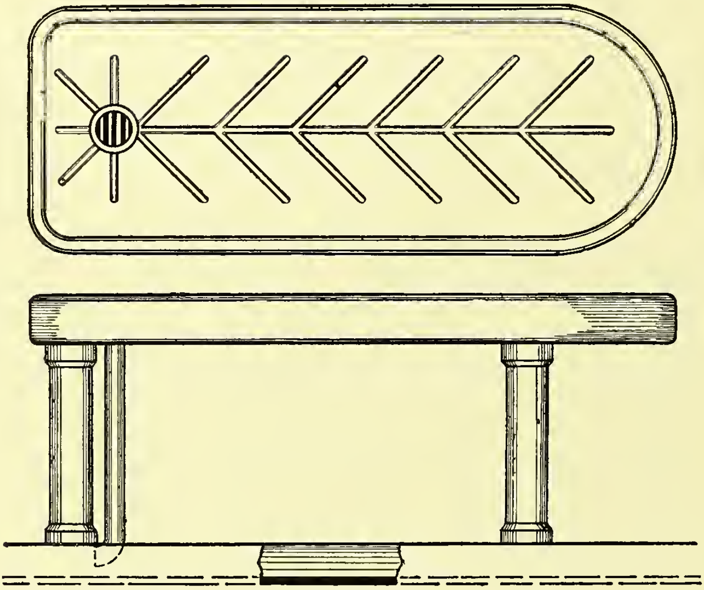


Fig. 489.—Grooved Post-mortem Slab on Fireclay Pedestals

vitreous-enamelled cast iron is sometimes preferred, being lighter and easier to move. The slabs have a fall either to a centre or side outlet, and a raised curb is usually provided around the edge. The surface may be grooved as shown in fig. 489, or of the shape illustrated in fig. 491, which

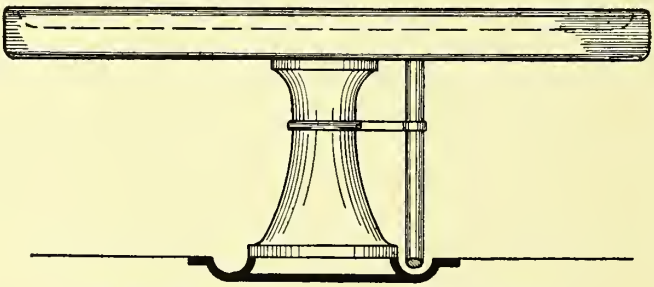


Fig. 490.—Revolving Post-mortem Slab on Cast-iron Pedestal

shows two side outlets; or the top can be simply dished with a fall to the outlet.

Supports for post-mortem tables are made either of iron or fireclay, according to whether they are movable or fixed. The pedestal supports shown in fig. 489 are of enamelled fireclay, and the table is a fixture. Fig. 490 illustrates a white-glazed fireclay top, fixed on an enamelled cast-

iron pedestal having ball bearings to enable the table to be easily turned. The bottom of the pedestal is fixed to the floor by bolts and nuts.

A short detachable waste pipe of brass, enamelled iron, or copper, having a grating at the inlet, is most often attached to the table. The waste pipe is arranged for the drainings to be received in a bucket placed under the table, or made to discharge into a channel, as shown in fig. 489, either entirely open or covered with a metal grid, and leading to a trapped drain inlet.

Fig. 491.—Post-mortem Slab with Two Outlets

Wooden Curbs.—To obviate the chipping of the front edge of glazed-ware sinks, teak insets, rims, rolls, or curbs can be advantageously fixed on the edge as illustrated in fig. 475. To minimize the risk of breakages of china or glass, movable wooden grids, of oak, teak, or ash, of the kind shown in fig. 484, may be laid in the bottom of the sink.

Drainers.—Enamelled-fireclay drainers have come much into vogue, and for public institutions their use is incumbent owing to their impermeability. For domestic use, drainers of oak, teak, or ash are often preferred, as they are softer and less slippery than those made of pottery. With some sinks the drainers are made to fit inside, as shown in fig. 475, resting on specially moulded projections or metal lugs, and either hinged or made to

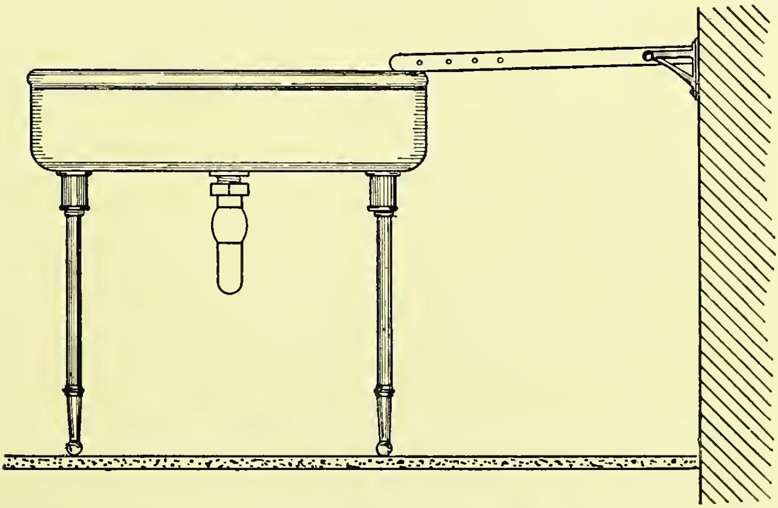


Fig. 492.—Sink with Drainer at Side

lift out. In other cases they are supported by a cantilever or bracket at one end, the other end resting on the sink, into which it drains, as shown in fig. 492. The last is the usual arrangement.

The surface of drainers, whether of pottery or of wood, ought to be fluted so as properly to drain the articles placed thereon. The objection to wood is its perviousness, and draining boards are therefore sometimes covered with sheet lead or tinned copper. Zinc and galvanized iron are also occasionally used, but are decidedly inferior.

In hospitals removable draining slabs or shelves of marble or glass are often fixed on small metal cantilevers, and held in position by metal clips, as shown in fig. 488.

Sink Supports.—Sinks, more often than not, are carried on wooden supports or brick piers, and, not infrequently, the space beneath the sink is enclosed by a wooden casing, fitted with a door so as to form a cupboard, in which to store utensils. Such enclosures are not commendable.

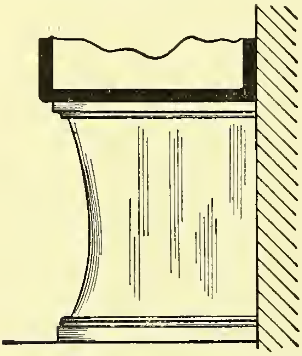


Fig. 493.—Enamelled-fireclay Pedestal for Sinks

When fixed in an angle, sinks are frequently supported at one end by a projecting corbel, leaving only one independent support to be provided, which may take the form of the enamelled-fireclay pedestal shown in fig. 493; but objection is sometimes raised to this support, as it encloses the space under the sink, and the corners facilitate the accumulation of filth. If floor supports are demanded, they should consist of galvanized- or enamelled-iron legs or standards, as illustrated in fig. 492, which are to be preferred to the type of standard found in fig. 485. The best method of fixing is by means of galvanized- or enamelled-iron cantilevers built into the wall, which place no obstacle in the way of the free circulation of air around the fitting and the cleansing of the surroundings.

Gratings.—The only means of escape for the waste water in many scullery sinks is through a grating having a few small holes, as in No. 2, fig. 473. This is a constant source of annoyance, owing to the ease with which the holes are stopped up, and is a serious defect, as the sectional area at the entrance of the waste pipe is so restricted by the design of the grate that the quick passage of water is prevented. Pottery grates are now seldom used, and are unsuitable, as they are easily broken, and the perforations are generally very small. Brass gratings are now most often employed; the perforations ought to be at least equal to the cross section of the trap and waste pipe, otherwise the latter will never be properly cleansed. A cobweb grating of the kind shown in fig. 494 is more efficient than the grating illustrated in fig. 473. For sinks in which it is desired to retain the water, the orifice must be made so that a standing waste (as in fig. 474) or a waste plug (as in fig. 476) can be inserted. In these forms of outlet the gratings are sunk.

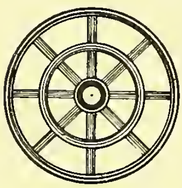


Fig. 494.—Cobweb Grating for Sink

For all sinks the outlet should be at least 1 in. larger in diameter than the internal size of the waste pipe, so as to secure a more rapid emptying of the sink and an increase in the scouring force of the water upon the attached trap.

Connections.—If the lead trap or waste pipe is connected directly to the sink, as shown in fig. 495, it should have an enlarged mouth or be cone-shaped. In No. 1, fig. 473, the only possible method of attaching the waste pipe is to butt it against the under side of the sink around the moulded lip,

and make the joint with Portland or red-lead cement. A better method is illustrated in fig. 495, the lead waste pipe being brought through the orifice in the sink, tafted into the groove on a bed of red-lead cement, and provided with a metal grating soldered to the lead pipe.

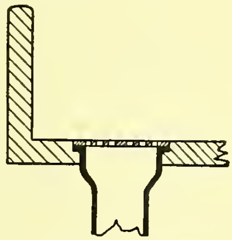


Fig. 495.—Enlarged Mouth of Waste Pipe or Trap

Fig. 499 shows an improved form of outlet, consisting of a washer with fly nut and union for connecting to the waste pipe. With this form of waste-pipe connector, a sound and reliable connection can be made to any form of pottery sink, with the aid of a rubber, asbestos, or metallic-lead washer.

For metal-lined sinks the lead trap is either soldered directly into the bottom of the sink and fitted with a brass grate, or a metal washer is connected in the same manner by a wiped joint. In both cases care must be taken to recess the outlet sufficiently to allow the grating or washer to be below the surface of the sink, as shown in fig. 496; for if the grating is permitted to stand above the sink bottom, it is likely to be torn off by the rim of a pail or other utensil, and in any case the sink will never be properly drained.

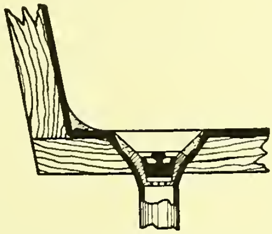


Fig. 496.—Plug Waste for Lead-lined Sink

For laboratory sinks recourse must be had to stoneware, lead, or vulcanite fittings. Fig. 497 shows an excellent outlet for laboratory sinks. It has a perforated vulcanite bucket to prevent broken glass and other débris from entering the waste pipe. The washer is ground in, and can be fitted with a solid vulcanite plug or a standing waste. A rubber washer is used to secure a water-tight joint. A somewhat similar perforated bucket or strainer made of copper, but without a plug washer, is made for ordinary domestic sinks.

Wash tubs are generally fitted with solid plugs and chains.

Waste plugs are commonly made of gun metal or brass, ground in to fit flush with the top of the washer, and a ring or eyelet is affixed to which a chain is generally attached. Plugs are also made of metal covered with rubber, which are less noisy and are not so likely to damage the surface of the sink. Plugs made entirely of indiarubber can also be had, but are affected by hot water. The most perfect plug is one made of vulcanite, which is non-absorbent, durable, and very light.

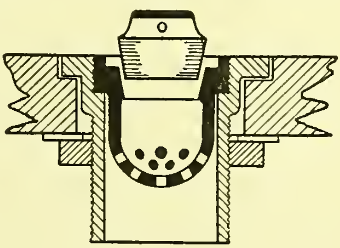


Fig. 497.—Vulcanite Outlet for Laboratory Sink

Standing wastes have to some extent superseded the ordinary solid plug, and combine in the one fitting an overflow and waste. They are replicas in miniature of the old-fashioned standing or trumpet cistern wastes, and are manufactured of similar materials to the solid plugs and in a variety of shapes. For cast-iron sinks galvanized cast-iron wastes are sometimes used, but for all classes of sinks

those made of vulcanite are to be preferred, as metal fittings are rather heavy and endanger the enamel of the sink. Some standing wastes are fitted with a handle or loop, so that the fitting, when not in use, can be hung upon a small hook attached to the sink, as shown in fig. 483. Others are fitted with a projection on the outside, which passes through a corresponding slot in the guide plate; on lifting the waste and giving a quarter turn it is held in position clear of the outlet. Other kinds of waste fittings that can be adapted to sinks will be described in the chapter on Lavatories.

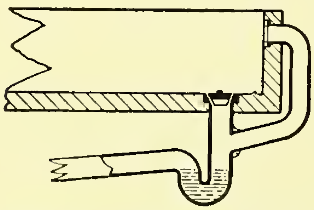


Fig. 498.—Old Type of Overflow from Sink

The waste outlets in sinks of modern patterns are often recessed, as shown in fig. 474, particularly where a combined standing waste and overflow is used. This method is an advantage, as it leaves the sink clear of projections, and lessens the risk of displacement of the standing waste.

Overflows.—Every sink adapted for washing-up purposes should be fitted with an overflow. At one time it was the fashion to provide a separate outlet and connect it to the trap by means of a short pipe, in the way illustrated in fig. 498, the outlet from the sink taking the form of a number of small perforations in the pottery. The method is open to objection, as it is quite impossible to obtain access for cleansing, the result being that sour smells are emitted from the accumulation of filth in the pipe.

An advance upon this is illustrated in fig. 499, which consists of a removable brass overflow grate and tailpiece with union, the overflow pipe being connected to the trap below the level of the standing water.

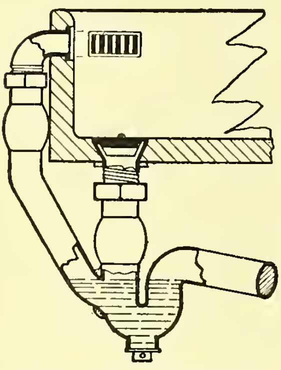


Fig. 499.—Brass Overflow Grate and Tailpiece

An open overflow that is accessible for cleansing is now considered almost indispensable. Fig. 500 illustrates an overflow made in the pottery itself, the water escaping from the sink through a number of perforations in the side. An opening is continued up to the top edge of the sink, and the orifice is fitted with a small removable brass grate. In figs. 475 and 476 are shown overflows of the weir type, the inlets being below the top edge of the sink. All these overflows discharge into the waste outlet below the plug, and are easily accessible. The orifice can be left entirely open or fitted with a small brass grate. The combined overflow and standing waste, illustrated in fig. 474, has certain advantages over a fixed overflow, as it can be removed and scalded without any difficulty.

Wash tubs and small drip sinks are not, as a rule, provided with overflows, and the former are generally fitted with short waste pipes discharging into a channel, which in turn discharges over a trapped drain inlet.

Materials for Waste Pipes.—Except for laboratory sinks, where all

connections must be of the materials previously indicated, iron, lead, stoneware, and zinc are commonly used. Zinc is totally unsuitable, and in London its use is debarred by one of the by-laws, which requires sink and lavatory waste pipes to be of lead, iron, or stoneware. Lead is to be preferred if the waste pipes are short or fixed outside, which would enable a form of expansion joint, such as illustrated in fig. 513, to be used so as to allow the metal to freely expand and contract without breaking. For

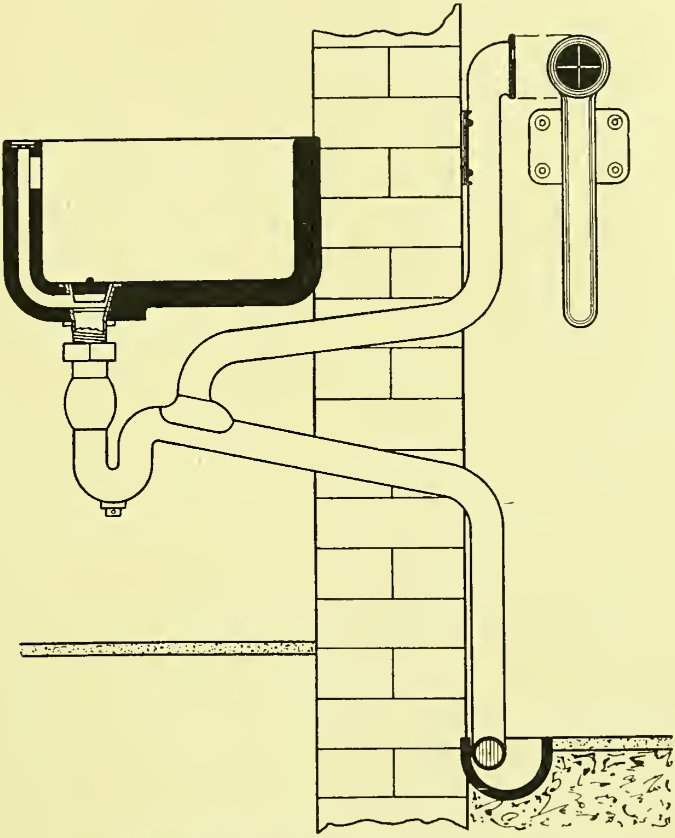


Fig. 500.—Sink with Overflow open at the Top, and Trapped Waste

internal positions cast- or wrought-iron pipes should be employed, either galvanized or coated with a suitable solution. Cast-iron pipes may be glass- or vitreous-enamelled inside, and must be of sufficient strength to enable the joints to be caulked with metallic lead; wrought-iron pipes should be of steam strength with screwed joints.

Size of Waste Pipes.—The nearer the waste pipe approximates to the size actually required for conveying the waste water from the sink outlet, the more efficient will it be in action. In a large number of houses waste pipes are found 3 to 4 in. in diameter, a size that is neither requisite nor desirable. Individual sinks never require a waste pipe larger than 2 in., and frequently a pipe $1\frac{1}{2}$ in., or even $1\frac{1}{4}$ in., is quite sufficient.

Trapping of Waste Pipes.—The by-laws in force in London provide that lavatory and sink waste pipes shall "be trapped immediately beneath such lavatory or sink by an efficient siphon trap with adequate means for inspection and cleansing, and which shall be ventilated into the external air whenever such ventilation may be necessary to preserve the seal of such trap". A trap fixed directly under the sink and fitted with a cleansing screw, as in fig. 500, is thus required for every waste pipe.

Ventilation.—For an isolated sink at the ground-floor level, where the waste pipe is short and simply turned through the wall into the external air, trap ventilation is not generally required to ensure the maintenance of the seal, but even under these conditions it is as well to provide a vent or "puff" pipe, fixed as shown in fig. 500, so as to obtain a circulation of air through the waste pipe. Where, however, a number of sinks are connected to one waste pipe, the waste pipe should be carried up as a ventilating shaft to a suitable position, together with trap-ventilating pipes from the different fittings.

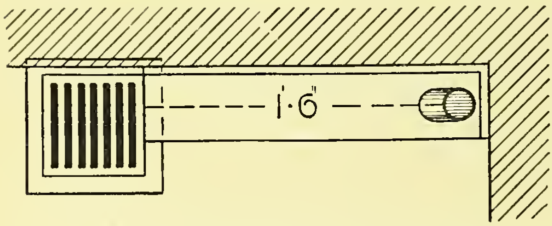


Fig. 501.—Waste Pipe discharging into Channel leading to Gully

Hopper Heads and Gullies.—The practice of discharging sink waste pipes into hopper heads is to be deprecated. It is better that the waste pipe should be carried down direct, and made to discharge into a trapped gully below the grating, provided there is no by-law in force making it compulsory (as set out in the model by-laws of the Local Government Board) to discharge the waste pipe into an open channel with the outlet 18 in. distant from the gully, as illustrated in fig. 501. The by-law reads as follows: "A person who shall erect a new building . . . shall . . . cause the waste pipe from every bath, sink (not being a slop sink constructed or adapted to be used for receiving any solid or liquid filth), or lavatory, the overflow pipe from any cistern and from every safe under any bath or water closet, and every pipe in such building for carrying off waste water, to be taken through an external wall of such building, and to discharge in the open air over a channel leading to a trapped gully grating at least 18 in. distant".

This requirement is designed to secure complete disconnection between the waste pipe and the drain, but it is a questionable arrangement, as the flow of the water is impeded, and the channel and grating become foul in use, the grating being often choked with leaves and débris, with the result that foul greasy water is discharged over the surrounding paving or ground. By connecting the waste to the back or side inlet of a gully above the level of the standing water, the waste arrangement is maintained in better order and with freedom from nuisance, and a fresh-air inlet is provided by means of the gully grating.